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**A study of consonant confusions in a group of cochlear impaired individuals demonstrating rollover**

**Dunn, Jan, Ph.D.**

**City University of New York, 1993**

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A Study of Consonant Confusions in a  
Group of Cochlear Impaired Individuals  
Demonstrating Rollover

by


Jan Dunn

A dissertation submitted to the Graduate Faculty in  
Speech and Hearing Sciences in partial fulfillment of  
the requirements for the degree of Doctor of Philosophy,  
The City University of New York

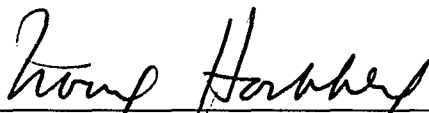
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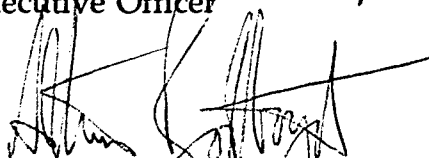
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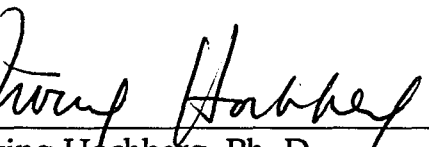
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## Abstract

A STUDY OF CONSONANT CONFUSIONS IN A GROUP  
OF COCHLEAR IMPAIRED INDIVIDUALS DEMONSTRATING ROLLOVER

BY

Jan Dunn

Adviser: Professor Harry Levitt

The present study focused on the types of consonant confusions made by cochlear-impaired listeners demonstrating rollover at intensities above (I+) and below (I-), the point of maximum recognition. The hypothesis to be tested stated that there would be a difference in the pattern of confusions at these two intensity levels even though the actual recognition scores were identical.

Ten cochlear-impaired subjects listened to final consonant subtests of the CUNY Nonsense Syllable Test in a cafeteria noise background at a S/N of +10. The main finding of the combined data was that voiceless consonants showed a more rapid change in performance with increasing intensity than did the voiced consonants.

Voiced consonant data showed a significant target consonant effect that approximated an ordering by manner of articulation and a vowel context effect showing greater error rates at I+ when consonants were paired with /u/. In addition, it was found that only in the case of a vowel context of /u/ did between-category errors exceed within-manner errors.

Voiceless consonant data showed a tendency for subjects to make few errors for /s / and /sh/ while frequently missing /th/ and /f/. The effect of a context of /u/ was again evident. When grouped by relative acoustic strength, it was found that weaker consonants show greater error rates but, more

importantly, there was a significant interaction of stimulus level and vowel context.

A log linear analysis of the data showed the model comprised of the response - target interaction plus the level effect plus the vowel context effect was adequate to predict the obtained confusion matrices. The response target interaction was the dominant term and, for voiced consonants, this interaction was largely explained by performance with nasal consonants.

The results were consistent with a model in which the I- performance could be attributed to a hearing threshold effect while the I+ performance could be attributed to an upward spread of masking effect. Alternatively, non-linear effects noted in the impaired cochlea could have produced the obtained results.

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I would like to acknowledge the invaluable assistance and guidance provided by my Committee consisting of Dr. Harry Levitt, Dr. Irving Hochberg, and Dr. Arthur Boothroyd. I would be derelict if i did not single out Dr. Levitt to thank him for his patience and encouragement. Likewise, I am aware that Dr. Hochberg bent over backwards to keep me enrolled and looked the other way when I legitimately could have been removed for overstaying my welcome. I suppose I must hold some type of longevity record. Thank you both.

My appreciation to Dr. R. W. Matthes for putting things into perspective for me. My thanks also to Warren A. Sweeney and Janine Henrickson for making me laugh when I thought I couldn't.

None of this would have been possible if my brother Gary hadn't provided the computer power. I thank him for that and for giving me the means to enjoy a rewarding hobby.

I apologize to my wonderful children, Alex and Lesley, for all the times I was cranky during a very long and anxious time.

Thank you, Manina. You know how difficult this whole process is. Your patience, support, and encouragement made it bearable. I will remember it always.

I would like to dedicate this manuscript to my dear friend Jan Hilley. While her help in proofreading was invaluable, she provided something far more important. She has opened my eyes to my own worth. She has shown me the rewards of friendship. She has educated me about being human.

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## CHAPTER 1

### INTRODUCTION

In the assessment of speech discrimination ability, it has been demonstrated that for most subjects, performance improves as signal intensity is increased until a point of optimum performance is attained (Carhart, 1952). This point can be identified as (P<sub>MAX</sub>, I<sub>MAX</sub>) where P<sub>MAX</sub> is the speech discrimination score and I<sub>MAX</sub> is the lowest signal level at which P<sub>MAX</sub> occurs. In most cases, increasing the signal level above I<sub>MAX</sub> does not result in a change in discrimination score. However, investigators have shown that both normal and hearing impaired individuals listening at high intensity levels and/or with high level masking noise often show a decrease in intelligibility at signal levels above I<sub>MAX</sub>. Pollack and Pickett (1957) showed normals listening at overall speech levels of greater than 120 db SPL generally show a 10 percent decrease in discrimination scores compared to their maximum discrimination score. The addition of white noise at the same level resulted in a 35 percent decrease in discrimination when compared to the maximum discrimination score.

A similar decrease in discrimination ability at levels greater than I<sub>MAX</sub>,

has been observed with certain types of hearing loss. However, the level at which the decrease in performance is observed is considerably lower than the 120+ db used by Pollack and Pickett. Subjects with lesions of the VIII Nerve frequently exhibit a decrease in performance when stimuli are presented at levels greater than IMAX (Jerger and Jerger, 1971; Dirks et al, 1977). The term rollover is used to describe the phenomenon. Jerger and Jerger, 1971; Dirks et al, 1977, Gang, 1976; Shirinian and Arnst, 1980; Hedgecock, 1955; Shultz and Streepy, 1962; Huizing and Reyntjes, 1952, have also noted this rollover in some subjects with cochlear hearing loss, frequently in cases of Meniere's Disease, and also with geriatric subjects. There is also evidence that rollover may be associated with lesions of the brainstem, cerebellum and cerebrum, particularly when frequency or temporal parameters of the signal are modified as with filtered speech and compressed speech tests (Jerger and Jerger, 1971; Bocca and Calero, 1963; Calero and Antonelli, 1963).

The magnitude of rollover can be specified by Rollover Index, RI, defined by Jerger and Jerger (1971) as:

$$RI = [ P_{MAX} - P_{BMIN} / P_{MAX} ]$$

where P<sub>BMIN</sub> is "the lowest score above the PB max". For reasons of safety the highest tested level should not exceed Loudness Discomfort Level.

Both Jerger and Jerger (1971) and Dirks, et al (1977) found the Rollover

Index to be a sensitive means of differentiating between sensory and neural impairment. They showed that for cochlear losses, the RI was typically below 0.40 whereas for neural losses the RI was typically well above 0.40. It is important to note that the sensitivity of the RI is dependent upon the highest level tested. If testing is terminated well below LDL, the calculated RI may be low leading to erroneous conclusions.

The studies cited thus far indicate that rollover can occur with either sensory or neural pathology. Rollover associated with neural pathology has received the major interest in research studies, probably because it is more common in pathologies of this type. Rollover associated with sensory loss has not been investigated as extensively, despite the fact that the presence of rollover may have implications for the fitting of hearing aids. Great care in gain selection is needed for a person exhibiting rollover if maximum benefit is to be obtained from amplification.

The possible causes of rollover in individuals with sensory hearing loss, and the nature of errors made by subjects demonstrating rollover have not been studied in great detail. Most studies of speech perception have been made at or below IMAX, not above IMAX. In general, these studies focus on consonantal errors since it is believed that consonants convey most of the speech information for intelligibility. In addition, consonant perception is greatly influenced by hearing loss. This study focuses on patterns of consonant errors above and below IMAX for cochlear impaired subjects who demonstrate rollover.

The type of data that a study of this nature would obtain is not currently available. The results of such a study could better define the nature of rollover in individuals with cochlear hearing loss and perhaps give an indication of an underlying cause of the phenomenon. In addition, the results of this study would increase our knowledge of the type of phonemic errors cochlear impaired subjects make at relatively high levels.

## CHAPTER 2

### RELATED LITERATURE AND HYPOTHESIS

#### Consonant Confusions

A major focus of research on consonant confusions in normal listeners has been to classify and interpret the error patterns obtained. A classic study of this type is that of Miller and Nicely (1955). In this study, the authors investigated the ability of a group of normal listeners to recognize sixteen consonants presented under conditions of high and low pass filtering with no competing noise background and unfiltered with speech stimuli presented in a random noise background at various signal to noise ratios. The results were interpreted in terms of how various articulatory features such as voicing, nasality, place, manner, silibance, duration, affrication etc. were perceived. Voicing and nasality were found to be least affected by competing noise while place (front, middle back) was most susceptible to masking by white noise. High pass filtering resulted in comparable reductions in the perception of most features, i.e. as low frequency information is removed, the perception of all features is reduced. The results of low pass filtering is very similar to that obtained for the competing noise condition.

The conclusions of Miller and Nicely were based upon information theory analysis combined with visual inspection of the confusion matrices. New

statistical techniques for analyzing confusion matrices have been developed and in a recent paper, Bell, et al (1988) used the method of log-linear analysis to model the confusion patterns. Their results were similar to the conclusions of Miller and Nicely with respect to the major effects of noise and low pass filtering. However, while Miller and Nicely found no systematic pattern to the errors under high pass filtering, the log-linear analysis showed specific effects of small magnitude. For example, they showed that plosives and fricatives were more susceptible to the effects of high pass filtering.

In an alternative approach, Dubno and Levitt (1981) examined acoustic characteristics of the speech signal in noise and related them to the confusion patterns of normal listeners. Using the City University of New York Nonsense Syllable Test (Resnick, et al, 1975) in a background cafeteria noise, confusion matrices and acoustic analytic data were obtained. They found that the acoustic characteristics showing the highest correlation with speech discrimination scores in quiet were consonant energy, consonant duration, and the origin frequency of the second formant transition. Under a noise condition, the best predictors were consonant to noise ratio, consonant spectral peak frequency, and consonant duration. They also observed that the relative frequency of specific confusions is approximately constant. This is to say that the pattern of errors is constant with a proportional reduction in all confusions as speech to noise ratio (or signal intensity for speech in quiet) is increased. Other findings relevant to the present study include greater confusions for final consonants versus initial consonants,

greater confusions for voiceless versus voiced consonants, and a strong vowel context effect.

A major focus of research concerned with phonemic errors made by the hearing impaired has been the relationship between pure tone configuration and the types of errors made (Owens, et al, 1972; Reed, 1975). In addition, the importance of various distinctive features has been evaluated to determine which features are most affected by hearing loss (Bilger and Wang, 1976; Reed, 1975).

There have been conflicting findings relative to the correlation of audiogram configuration and consonantal error patterns. Owens et al (1972) concluded that the correlation between the two was poor with the exception of a high incidence of sibilance feature errors associated with sloping losses above 2 Khz. On the other hand, Reed (1975) and Bilger and Wang (1976) found a stronger relationship between hearing loss configuration and obtained error matrices. For example, it was found that a group with flat or rising audiograms showed poor performance on nasality, high/anterior place of articulation, and continuance but made few sibilance, duration or voicing errors. In contrast, a group with sloping high frequency loss demonstrated very poor perception of sibilance but made few errors for voicing, nasality and high/anterior place of articulation. An additional finding of these studies indicated excellent test-retest correlation for groups ( $r=.960$  to  $.985$ ) and somewhat less for individual subjects ( $r=.83$  to  $.937$ ).

Dubno, Dirks, and Langhofer (1982) used the CUNY Nonsense Syllable Test to evaluate the recognition ability of subjects with mild to moderate sensorineural loss. Consistent with Dubno and Levitt's findings using normal subjects, voiced consonants produced fewer errors than did voiceless consonants. Manner of articulation was found to have a significant effect on error scores with plosives and fricatives showing higher error rates than nasals, affricates, and glides. Place of constriction also had a significant effect in that back consonants showed low error rates (particularly when paired with vowel /i/). In addition, a significant vowel context-manner interaction was observed where error rates were low for affricates and nasals paired with /a/ as opposed to /i/ and /u/. Relative to audiogram configuration, subjects with a steeply sloping loss did significantly poorer than those with flat or gradually sloping audiometric configurations.

Gordon-Salant (1985) investigated changes in phoneme perception within nonsense syllables as a function of signal to noise ratio. Although using a different method of analysis (INDSCAL), the author found results consistent with previous investigators relative to feature perception. Of particular note, it was found that the pattern (not number) of errors was similar for both normal and impaired listeners when both groups listened to speech with a noise background present.

Most of the studies cited obtained data at only one intensity level, generally 40 db re SRT. In addition to Dubno and Levitt (1981), Wang and Bilger (1973)

considered the effect of presentation level. The latter investigators tested normal hearing subjects listening to nonsense syllables at levels of 50, 65, 80, and 95 dB SPL. Their data obtained in a quiet background showed the presence of rollover of approximately ten percent. No error matrices were presented for this condition. When the stimuli were presented in a noise background (S/N ranged from -10 to +15 dB), a significant interaction of S/N and intensity was reported. As summarized by Wang and Bilger, "Absolute level...produced systematic differences in performance, with the two higher levels, 80 and 95 dB, producing slightly lower discrimination scores. These differences were most marked at moderate S/N's." While rollover was noted, error frequencies were pooled across intensity levels with the result that confusion matrices for different signal levels could not be extracted from the published data.

Two studies which did include presentation level in the study of phonemic confusions were those of Dreschler (1986) and Hannley and Jerger (1985). Dreschler, using an INDSCAL analysis similar to that used by Gordon-Salant, analyzed the errors of hearing impaired subjects on a consonant-vowel-consonant syllable task at 3 intensity levels (the level yielding 50 percent intelligibility scores, the 50 percent level +5 db, and the 50 percent level -5 dB) both in quiet and with a speech spectrum shaped noise at a level judged most comfortable by each subject. Among the findings of this study was the deterioration in perception of voicing and nasality features in noise. Furthermore, the nasality feature is influenced more when the consonant was in a final position.

The Hannley and Jerger (1985) study compared the phonemic confusions made by a group of cochlear impaired listeners and a group of confirmed retrocochlear listeners where only the retrocochlear group showed rollover. Using Harvard PAL-50 word lists, confusion matrices for each phoneme within the stimuli were derived. Rollover was found to be related primarily to an increase in error rate for vowels. Error rate for consonants was relatively stable. Specifically, in the group showing rollover, as signal level increased from 80 to 110 dB, vowel error rate doubled while error rate for stops and fricatives did not change.

To summarize, a number of studies such as those of Bilger and Wang (1976) and Dubno et al (1982) have shown that both normal and impaired listeners produce distinct phoneme error patterns. Among these patterns are a tendency to make more errors for voiceless consonants as opposed to voiced consonants and relatively few errors involving the nasality feature. Studies such as that of Wang and Bilger suggest that the types of errors vary with pure tone configuration. The effect of intensity on these error patterns has not been demonstrated adequately. There is also apparent inconsistency among the few studies that do consider intensity effects. To date, there has been no published study evaluating the error patterns of cochlear impaired who demonstrate rollover.

### Factors Related to Rollover in the Cochlear Impaired

Because rollover in cochlear hearing loss has not been subjected to

extensive investigation, there is relatively little information as to which factors may contribute to rollover in this group. There is evidence that rollover and recruitment can occur concurrently (Eby and Williams, 1951; Huizing and Reyntjes, 1952; Hedgecock, 1955; Shultz and Streepy, 1967). Flottorp (1970) associated rollover with distortions within the cochlea and specified that recruitment was a manifestation of the type of distortion that may result in rollover. The observation that rollover is noted frequently in Meniere's Disease, of which recruitment is characteristic, provides additional support for the association of rollover and recruitment. There is no evidence to suggest that rollover is a direct result of recruitment or of some pathology of the cochlea. At best it can be stated that in those cases of cochlear pathology in which rollover is observed, recruitment also is frequently noted.

It has been observed that rollover can occur when the speech signal is presented in a noise background even though no rollover is noted in quiet (Dirks et al, 1977). An explanation for this observation may be found in several studies of growth of loudness under noise (Richards, 1973; Stevens and Gurrao, 1967; Stevens, 1966; Hellman and Zwislocki, 1964). These studies demonstrated that in a normal ear, the loudness growth function for a pure tone accompanied by a noise masker closely approximates the loudness growth function of a recruiting ear under a no-masking condition. It has yet to be demonstrated that complex stimuli (i.e., speech) embedded in noise will also mimic recruitment. However, if this were true, then the addition of masker in the Dirks, et al study may have

produced a recruitment-like effect in the subjects showing rollover. Again, this would indicate an association between recruitment and rollover.

Rollover has also been observed in cases where the opposite of recruitment (de-recruitment) occurs. Hood (1968) described a sensory loss in which "loudness reversal" (de-recruitment) was observed. In addition, rollover is commonly observed in individuals with lesions of the VIIIth cranial nerve. De-recruitment is also characteristic of this type of impairment.

Milner (1982) has suggested two possible factors contributing to rollover, First, he theorized that at high intensity levels, brief peaks of the speech signal exceed loudness discomfort levels and, thus, are in a region of distortion. Once in a region of distortion, that peak does not contribute to the intelligibility of the signal. The result is less information available to the listener at high levels, even if the overall intensity is below the LDL.

A second factor suggested by Milner is upward spread of masking. He based his hypothesis on the finding that in his subjects, rollover began at a greater intensity level when energy below 700 Hz was filtered out. Conversely, when the energy below 700 Hz was present, rollover occurred at a lower intensity level. The assumption was that the presence of low frequency energy masked higher frequency cues resulting in rollover occurring at lower levels. This finding is particularly significant in view of the results reported by Pickett and Danaher, (1975). These authors, measuring F2 transition discrimination ability, found F1 could mask F2 transitions in a number of ways, including upward spread of

masking, forward masking, backward masking, and in dichotic situations, central masking. Interestingly, these findings were noted in both normal and hearing impaired listeners when the presentation levels were similar between groups. Wilson, et al (1973) also demonstrated spread of masking effects for speech stimuli in normal listeners.

Dorman et al (1986) identified a possible factor contributing to rollover when studying vowel perception in normal listeners. Listeners identified 10 synthetic vowels at a low sound level (72 dB SPL) and a high sound level (106 dB SPL). A 30 percent decrease in correct identification of vowels at the high sound level was found. Certain vowels, specifically /æ,a,^,U/, were missed more often than others but the authors were unable to differentiate whether the decreased performance was associated with formant height or formant spacing. They did find that the discrimination scores of short latency vowels (50 msec.) at the high level improved by 19 percent when the acoustic reflex was activated by a high intensity signal to the non test ear. The duration of these short vowels was less than the reflex latency for a 1 kHz. tone at the same intensity. Based upon these results, it would appear that rollover may be related to the presence or absence of the acoustic reflex. In interpreting these results, one should remember the attenuating effect of the reflex. The observed improvement in vowel identification noted with the reflex present may be due to the fact that the sound level reaching the ear is lower when the reflex is activated. Rollover is frequently observed in individuals with lesions involving the Auditory Cranial Nerve (VIII) and/or

higher neural structures. However, the magnitude of the effect is smaller in individuals with cochlear type lesions. Several studies including Jerger and Jerger (1971) and Dirks, et al (1977) have shown that Rollover Index of at least .40 can accurately differentiate cochlear loss from retrocochlear loss. The issue becomes somewhat clouded in the case of geriatric individuals who may present with a Rollover Index of greater than .40 yet manifest no obvious signs of neural pathology (Gang,1976). Jerger (1976) has argued that geriatric subjects probably have some diffuse neural degeneration to which testing for rollover is sensitive.

In summary, recruitment, upward spread of masking, temporal masking, and aging effects have been observed to coexist with rollover. However, the body of information on rollover in cochlear impaired subjects is small and occasionally contradictory. The most consistent findings suggest that upward spread of masking contributes to the effect.

## Rationale

The hypothesis for the current study is that the pattern of errors at a level below PB max will differ from the pattern of errors at a level greater PB max, even though the discrimination scores are equivalent. This would raise the possibility that different mechanisms may produce the errors above and below PB max.

A study designed to analyze the types of errors made by subjects showing rollover could have several important implications. First, if an analysis of phoneme confusions indicates that certain phonemic errors occur with rollover in a disproportionate degree, a screening test for rollover could be devised using these phonemes as stimuli. Secondly, if the data suggest that psychoacoustic mechanisms contribute to rollover, one might predict the likelihood of a subject demonstrating rollover from relevant psychoacoustic measurements (e.g. spectral or temporal spread of masking). The ability to make such predictions would be of great practical value when testing patients who, for one reason or another, cannot respond validly on a speech discrimination task. Finally, such a study has implications for the fitting of hearing aids. Excessive amplification may cause rollover and a concomitant reduction in intelligibility. In order to maximize intelligibility, it is thus necessary to know the factors affecting rollover.

## Statement of the Hypothesis

The present study was designed to evaluate the following hypothesis:

**In a group of cochlear impaired subjects demonstrating rollover, the pattern of consonantal errors will be different for a presentation level less than IMAX when compared to a presentation level greater than IMAX, although the total frequency of errors may be the same at both levels.**

### Definition of Terms

For the remainder of this document, reference will be made to points located along a typical performance-intensity function curve of a subject exhibiting rollover, as shown in Figure 2.1. The following nomenclature will be used.

**PMAX = the maximum discrimination score in a Performance Intensity function exhibiting rollover.**

**IMAX = the level at which the maximum discrimination score (PMAX) is obtained**

**I+ = a level above IMAX but below LDL; in this study, IMAX was set to LDL - 5 dB.**

$P_+$  = the discrimination score at level  $I_+$ .

$I_-$  = a level below  $I_{MAX}$  such that the discrimination score at this level ( $P_-$ ) is equal to  $P_+$  ; since  $P_-$  and  $P_+$  are subject to experimental error, they will be specified as equal if they do not differ significantly relative to their test - retest variability.

$P_-$  = the discrimination score at level  $I_-$

If  $I_-$  and  $I_+$  are chosen correctly,  $P_-$  and  $P_+$  are equal.

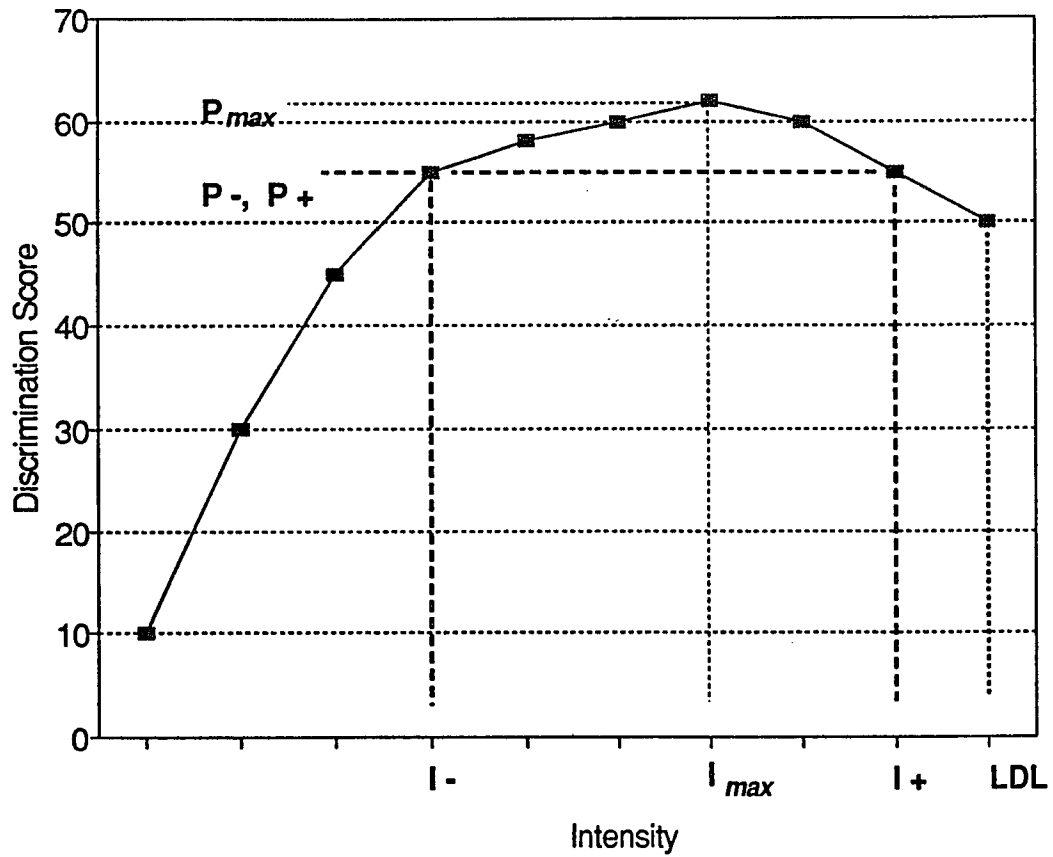


Figure 2.1 Points on a Performance-Intensity Curve Demonstrating Rollover. P refers to a discrimination score while I refers to the corresponding intensity.

## CHAPTER 3

### EXPERIMENTAL PROCEDURES

#### Subjects

Ten subjects were selected from the patient population of the Brooklyn Veterans Administration Medical Center. As with most VA Medical Centers, the patient population primarily consists of males ranging in age from 20 to 90+ years. Since it has been demonstrated that rollover is common in a geriatric population (Gang, 1976; Shirinian and Arnst, 1980), and it is open to question whether rollover in the elderly is due to a cochlear pathology (Gang, 1976) or an VIII Nerve or more central lesion (Jerger and Jerger, 1976; Shirinian and Arnst, 1980), all subjects were under the age of 60 (mean age=54.6 years). Furthermore, all subjects were free of neurological disease as evidenced by patient's reported medical history and a review of available medical records.

Pure tone audiograms showed no conductive component in the test ear at the octave frequencies from .25 to 4 kHz. This was confirmed with immittance measurements. Mean three frequency pure tone average (.5, 1, 2 kHz.) was 40.3 db HL. However, thresholds above 2 kHz generally were considerably poorer with a typical slope of approximately 15 db per octave above 2 kHz. Each subject's audiogram is presented in Appendix D. There were no specific controls

for the etiology of the hearing loss, other than that the loss have neither a conductive or retrocochlear component. However, in general, the majority of subjects described their hearing loss as one of gradual onset and slow progression. Six subjects attributed the onset of their hearing loss to noise exposure experienced during their military service and/or subsequent job related noise exposure. Subjects with a history of head trauma were excluded due to the possibility of concomitant central nervous system damage. No subject presented a history of ingestion of commonly known ototoxic agents such as aminoglycosides or anti-cancer therapeutic medications. Furthermore, no subject with a history of long-term renal disease was included (i.e. none had ever received dialysis). Two of the subjects reported a sudden onset of hearing loss with both describing waking up one morning with dizziness and loss of hearing. The remaining two subjects could not relate a specific causal factor to their hearing loss. Appendix D also identifies the probable etiology of the loss.

Participation was restricted to individuals demonstrating cochlear pathology with no evidence of conductive, VIII Nerve, or central pathology. Besides the medical history, criteria for determining cochlear site of lesion were as follows:

1. No loss of tonality or audibility in the test ear for 500 Hz and 2000 Hz tone presented at 20 dB SL for 60 seconds (Olsen and Noffsinger, 1974).
2. Type A tympanogram in the test ear.

3. No significant reflex decay manifested as less than 50% decay of the maximum compliance change generated by a 500 Hz tone presented at 10 db above the 500 Hz reflex threshold for 10 seconds, when stimulating the test ear and monitored with a standard clinical compliance meter.

These criteria, in conjunction with the medical history and the subject's description of the hearing loss and its onset were deemed reasonable assurance that the loss was not retrocochlear.

All subjects demonstrated a rollover of 9 percentage points or greater (P<sub>MAX</sub> minus P<sub>+</sub>) on a test composed of 100 final consonant items from the NST in a cafeteria noise at a S/N of +10 dB. In general, this absolute rollover converted to a Rollover Index of between .10 and .30. The decision to use a cafeteria type noise background is based on the normative study of Dubno and Dirks (1982). The 9% criterion, based upon this same study, was selected to avoid confusion between rollover and test-retest variation. The published results of these investigators relative to final consonants shows a test-retest standard deviation of 4.3 percentage points.

## Materials

The six protocols of the male talker version of the CUNY Nonsense Syllable Test (Levitt and Resnick, 1978) were utilized to obtain error matrices. This test

was selected primarily because it is relatively free of learning effects and because of its organization. Specifically, within each of the NST subtests, voicing, vowel context and consonant position are kept constant and each stimulus differs by no more than three distinctive features (generally place of articulation and/or manner of articulation). This simplifies construction and analysis of error matrices. The test has also been used in related studies; thereby allowing for comparisons with other experimental work.

The selection of a S/N was based upon results of a pilot study which showed cochlear impaired subjects frequently showed rollover at a S/N of +10 dB. The pilot study also showed that rollover was much greater for VC as opposed to CV syllables. For this reason, only the VC subtests of the NST were used. The cafeteria noise used was the same as that used by previous investigators (Levitt and Resnick, 1978) and has a spectrum similar to speech shaped noise whereby the intensity is flat through to 500 Hz and then decreases at a rate of 9 db per octave.

## Test Procedures

Testing took place in two stages. In the first stage, the stimulus levels of interest were estimated, these being LDL, I+, IMAX, and I-. These estimates were obtained for VC nonsense syllables in a vowel context of /a/, /i/, and /u/. A set of 100 VC stimuli from the CUNY NST subtests served as the test material for

this stage. LDL was first determined using a method of adjustment. In all cases, LDL was less than 114 dB SPL. In order to estimate IMAX, the stimuli were presented at progressively lower levels starting at LDL minus 5 dB and lowered in 5 dB steps. The level showing the highest discrimination score was used as an estimate of IMAX. This method of estimating IMAX is consistent with that used by Jerger and Jerger (1971) and Dirks, et al (1977) with one modification. The present study descended from LDL while the other studies ascend toward LDL. It should be noted that IMAX was used primarily as a reference point for the levels of interest, I- and I+. The level I+ was set at LDL minus 5 dB. Level I- was estimated by reducing the stimulus level below IMAX in 5 dB steps until a discrimination score equal to that at I+ (within two standard deviations) was obtained. According to Dubno and Dirks (1982), subjects with sensorineural hearing loss show a test-retest variability of 4.3 percentage points on the NST in the region of interest. Thus, the discrimination score at I- was chosen to be within 8.6 percentage points of the score at I+.

After the estimates of IMAX, I+, and I- were obtained, the second stage of testing commenced. In this stage, the VC subtests of the NST were administered twice at the three levels derived in the first stage. Each of the replications was separated by at least one week. In each test session, subjects were presented with three replications of each subtest at each level for a total of six replications for each test condition. The test protocols and order of presentation were randomized using a random number generating program.

These second stage discrimination scores obtained at IMAX, I+, and I-, known as PMAX, P+, and P- respectively, served as the basic data of this study.

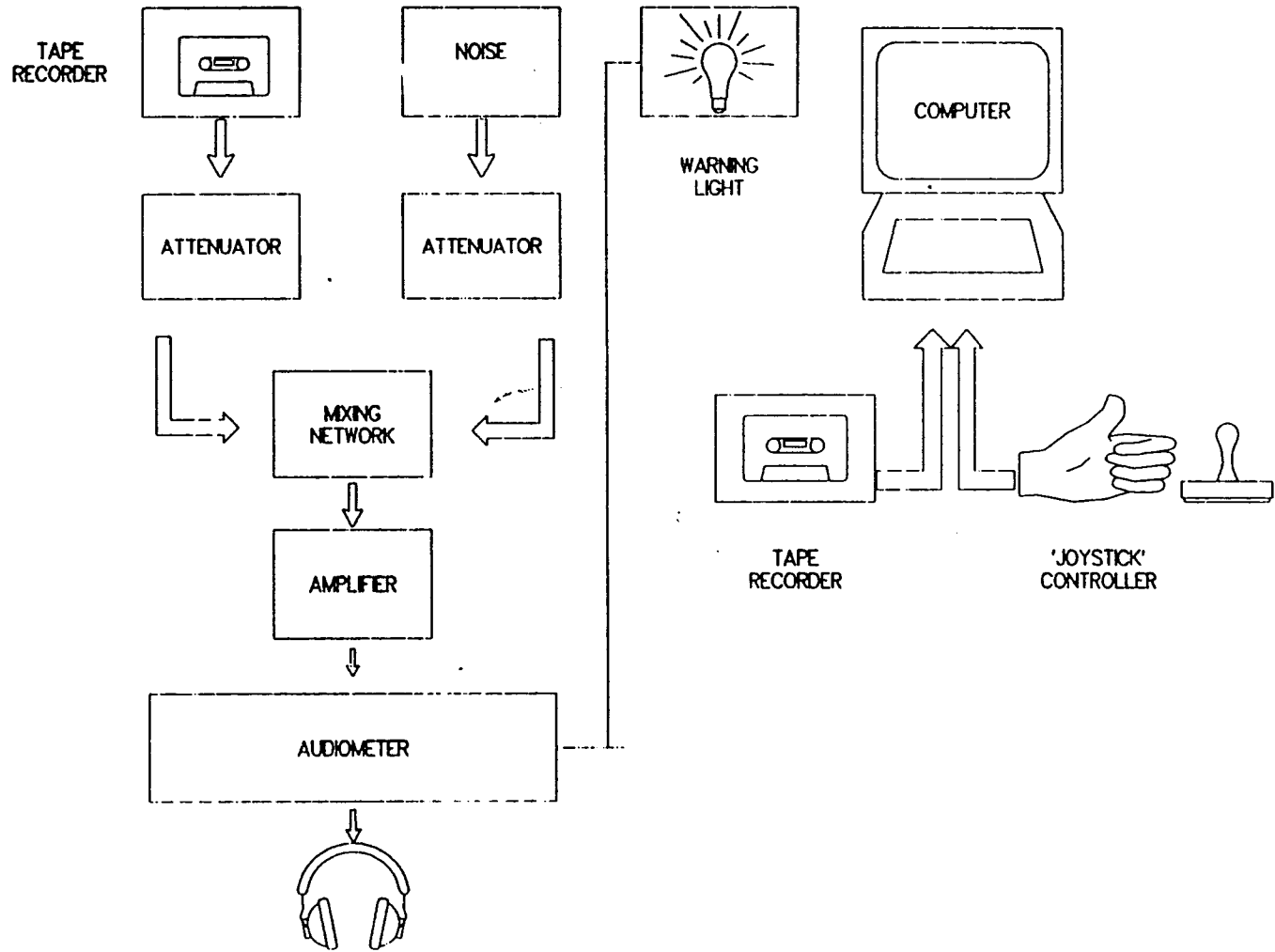
## Equipment

The instrumentation required to measure speech discrimination consisted of a system for presenting the test stimuli and a response system.

The equipment for presenting the NST included a Sony TC630 two-channel tape recorder, a Grason-Stadler 1701 Audiometer, a Macintosh power amplifier, components of the Grason-Stadler 1200 Series Programming System (amplifiers, attenuators, mixing networks, noise generators, and timers), and TDH-49 earphone in MX41/AR cushions. A schematic diagram of this instrumentation is shown in Figure 3.1.

The response system used was different from the answer book format frequently used with the NST. For the present study, the response foils were presented on a Zenith 120 video monitor under control of a Texas Instruments 99/4A Home Computer. Remote controllers (joysticks) were used to select the foil of choice. A Panasonic cassette recorder was used to load the control program and to save the responses for later analysis. Appropriate software to present the foils and record responses was developed using the BASIC language.

Figure 3.1 Instrumentation Used to Administer Test Stimuli.



## CHAPTER 4

### RESULTS

The data obtained in the study were subjected to three types of analysis. Firstly, a global analysis of the entire data set was performed to check for test-retest consistency, to determine the precision of matching I+ and I-, and to examine the effect of level on overall test scores. Secondly, a detailed analysis of performance at the I- and I+ intensity levels was performed. Voiced and voiceless consonant error data were analyzed separately because of differences in the structure of the data sets (i.e., there were nine voiced but only seven voiceless consonants in the set of test stimuli; the voiced consonants included nasals which do not have a voiceless cognate). In the course of the above analysis, the data were grouped by individual consonants, by manner of articulation, and by relative acoustic strength. The third analysis examined differences in the structure of the error matrices. In analyzing these error patterns, a hierarchical log-linear analysis was used to develop models of the data.

#### GLOBAL ANALYSIS

The following and all subsequent analyses will be in terms of error rates rather than percent correct identifications. This has been done in order to

facilitate comparison with the subsequent analysis of error patterns.

The test was administered twice to each subject as described in the Methods section. Each administration contained three replications of each consonant with each vowel for a total of six replications of each syllable. In addition, in order to reduce guessing an additional nonsense syllable, selected at random, was included in each subtest. When the extra syllable was present, the average score of the two syllables was used. For purposes of analysis, the data can be considered as consisting essentially of six replications.

In order to evaluate test-retest consistency between the two administrations of the test, a Chi Square contingency analysis was performed on the error scores (administration versus consonant type). There was no significant difference between the first and second administration for all subjects (Chi Square=125.5, 113 degrees of freedom). In order to increase the power of the statistical tests to be performed, the data for the two administrations combined for each subject. This resulted in a significant reduction in the number of empty cells in each of the error matrices, thereby increasing the sensitivity and reliability of subsequent analyses. The data are summarized in Table 4.1 which shows the number of errors for the I+ and I- conditions for both voiced and voiceless consonants for each subject as well as the combined errors. Table 4.2 shows the percent correct scores for each of the above conditions.

Referring to Table 4.1, it can be seen that although the I- level was adjusted to have roughly the same error rate as the I+ condition, an exact match

Table 4.1 Number of Errors Made on NST at Stimuli Levels I- and I+

	VOICELESS		VOICED		COMBINED	
	I-	I+	I-	I+	I-	I+
SUBJ A	72	71	82	77	154	148
SUBJ B	59	58	55	60	114	118
SUBJ C	51	52	53	74	104	126
SUBJ D	65	62	75	83	140	145
SUBJ E	53	63	79	82	132	145
SUBJ F	61	71	84	102	145	173
SUBJ G	75	77	95	96	170	173
SUBJ H	70	77	98	104	168	181
SUBJ I	54	54	68	64	122	118
SUBJ J	44	62	70	82	114	144
TOTAL	604	647	759	824	1363	1471
MEAN	60	65	76	82	136	147
ST. DEV.	10	8	14	14	22	22
MAXIMU	75	77	98	104	170	181
MINIMU	44	52	53	60	104	118

Table 4.2 Discrimination Scores for NST at Stimulus Levels I- and I+

	VOICELESS		VOICED		COMBINED	
	I-	I+	I-	I+	I-	I+
SUBJ A	0.50	0.51	0.54	0.57	0.53	0.54
SUBJ B	0.59	0.60	0.69	0.67	0.65	0.64
SUBJ C	0.65	0.64	0.71	0.59	0.68	0.61
SUBJ D	0.55	0.57	0.58	0.54	0.57	0.55
SUBJ E	0.63	0.56	0.56	0.54	0.59	0.55
SUBJ F	0.58	0.51	0.53	0.43	0.55	0.47
SUBJ G	0.48	0.47	0.47	0.47	0.48	0.47
SUBJ H	0.51	0.47	0.46	0.42	0.48	0.44
SUBJ I	0.63	0.63	0.62	0.64	0.62	0.64
SUBJ J	0.69	0.57	0.61	0.54	0.65	0.56
MEAN	0.58	0.55	0.58	0.54	0.58	0.55
ST. DEV.	0.07	0.06	0.08	0.08	0.07	0.07
MAXIMU	0.69	0.64	0.71	0.67	0.68	0.64
MINIMU	0.48	0.47	0.46	0.42	0.48	0.44

was not achieved. The average discrimination score at I- was 58% while at I+ it was 55%. This difference was not statistically significant. Similarly, none of the subjects showed a significant difference in test score between the I- and I+ conditions.

In order to obtain a perspective of the data, a 4-way repeated measures analysis of variance (repeated over subjects) was performed on the mean error rates.<sup>1</sup> The inverse sine transformation ( $y = \arcsin \sqrt{p}$ , where  $p$  is the measured proportion and  $y$  is the transformed datum) was used in order to stabilize the error variance (Brownlee, 1964). The factors included Stimulus Level (I-, IMAX, and I+), Vowel Context (/a,i,u/), Voicing (presence/absence), and Subjects. The results of that analysis are presented in Table 4.3. It can be seen that only the main effect Stimulus Level is significant ( $F=48.4, p<.001$ ). There are also significant interactions between Stimulus Level and Voicing ( $F=8.5, p<.003$ ) and Stimulus Level and Vowel Context ( $F=5.4, p<.002$ ).

A post-hoc analysis (Tukey Honest Significant Difference (HSD) test; Siegel, 1956) of the Stimulus Level effect was performed. This type of analysis separates data into groups where the elements within a group do not differ significantly. Elements may be common to more than one group but elements

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<sup>1</sup>The repeated measures model is conservative with the major source of variability being inter-subject differences and the assumption that the subjects are a randomly selected, representative sample from the population at large. As a consequence, any significant effects will be representative of the population at large. In the present study, since all conditions were repeated for all subjects, a completely balanced design was achieved and an alternate model, the fixed effect model, could be used. In the fixed effect model, each subject is considered to have an independent effect on the data. The results of such an analysis can only hold for the ten subjects included in the study and not for the general population at large. Therefore, in considering the following analyses, it should be noted that factors NOT involving Subjects were tested using a repeated measures model while between-subject differences and interactions terms involving subjects were tested using a fixed effects model.

that are not common to two groups differ significantly from one another. By way of illustration, assume this type of analysis is applied to four mean scores identified as A, B, C, and D. The resulting grouping is {A,B,C} and {B,C,D}. Since B and C are common to both groups, they do not differ significantly. In contrast, A and D are not common to both groups, and thus differ significantly from each other. It is convenient, when interpreting the results of the Tukey Honest Significant Difference test to arrange elements in order of magnitude. This facilitates the graphical representation of the groupings obtained by the test (see for example, Figure 4. 1, as discussed shortly).

The Tukey HSD test showed that error rates at the I- and I+ levels formed one group and that the error rate at IMAX formed another group. The conclusion to be drawn is that the IMAX condition produced a significantly lower error rate than did either I- or I+ while the error rate at I- and I+ did not differ significantly from each other.

The Stimulus Level by Voicing interaction was also subjected to a post hoc analysis. The analysis separated the data into four groups. As shown in Figure 4.1, the group with the lowest error rates consisted of the voiced and voiceless IMAX conditions. The second grouping contained the Voiceless Imax, Voiced I- and Voiceless I+ conditions. The third group included Voiced I-, Voiceless I+, and Voiced I+. The last group consisted of Voiced I+ and Voiceless I- interactions which had the greatest error rates. The conclusion to be drawn from this figure is that for the voiceless consonants, the error rate for the IMAX condition was

Table 4.3 Summary Table of Analysis of Variance for All Consonant Errors (L=Level; V=Vowel Context; S=Subject; Z=Voicing).

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	SIGNIF. LEVEL
Level	6.553	2	3.276	48.418	0.001
Vowel Context	0.002	2	0.001	0.048	0.953
Voicing	0.024	1	0.024	2.559	0.142
L x V	0.597	4	0.149	5.400	0.002
L x Z	2.056	2	1.028	8.457	0.003
V x Z	0.124	2	0.062	2.184	0.140
L x V x Z	0.205	4	0.051	1.376	0.261
Subject	0.605	9	0.067		
L x S	1.218	18	0.068		
V x S	0.384	18	0.021		
Z x S	0.083	9	0.009		
L x V x S	0.995	36	0.028		
L x Z x S	2.188	18	0.122		
V x Z x S	0.512	18	0.028		
L x V x Z x S	1.338	36	0.037		
TOTAL	16.881	179			

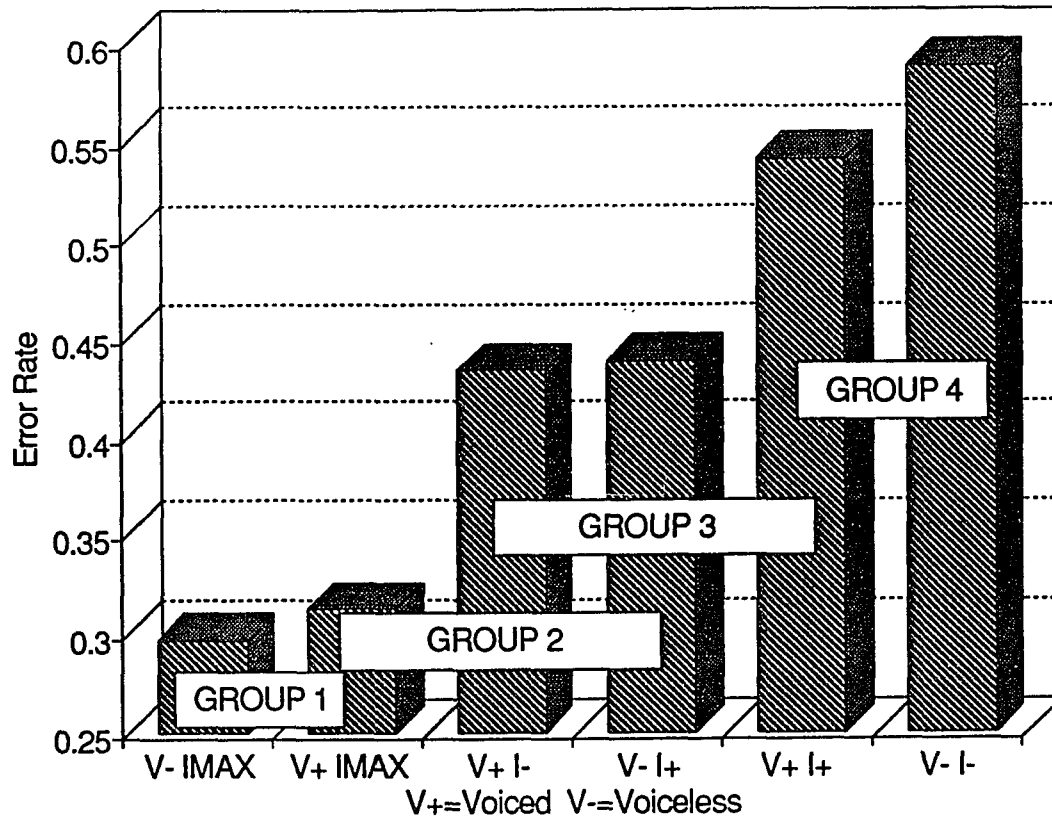


Figure 4.1 Stimulus Level by Voicing Interaction for All Consonants

significantly less than that for the I+ condition, which in turn, was significantly less than that for the I- condition. In contrast, for the voiced consonants, the error rate for the I- condition was not significantly greater than that for the IMAX condition. Although the error rate for the I+ condition was significantly greater than that for IMAX, it was not significantly different from that for I-. Figure 4.2 shows these interactions in a different format. It should be noted that the error rates for voiced and voiceless consonants behave differently on either side of IMAX in the slope of the function for voiceless consonants is steeper than that for voiced consonants on the I- side of the curve but less steep than that for the voiced consonants on the I+ side of the function.

The post hoc analysis of the Stimulus Level by Vowel Context interaction showed that there were two groups formed. The first group consisted of the Imax condition for the three Vowel Contexts. The second group included the six combinations of I- and I+ with the three Vowel Contexts. Again, it can be concluded that the IMAX Stimulus Level yielded significantly lower error rates for all three Vowel Contexts than did I- or I+. While I- and I+ did not differ significantly, there is an ordering where /u/ yields the highest error rates. Figure 4.3 shows the grouping and order within each of the two groups.

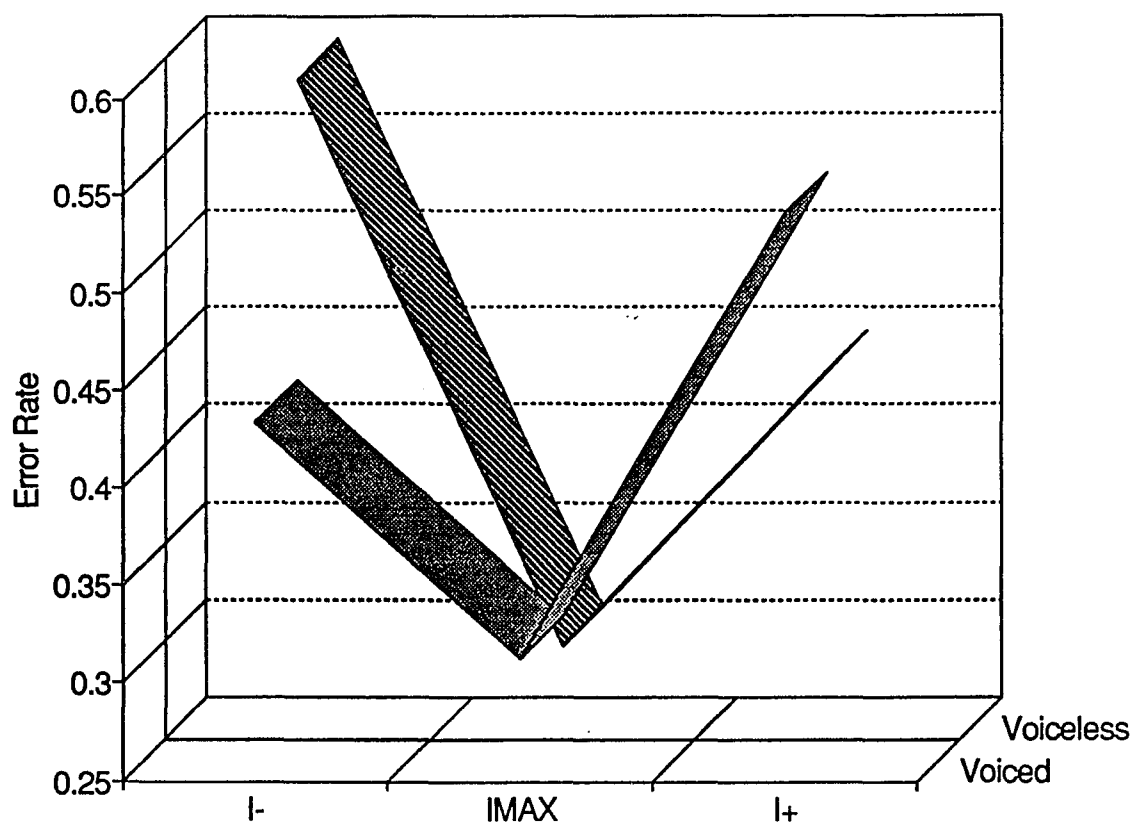


Figure 4.2 Stimulus Level by Voicing Interaction for All Consonants

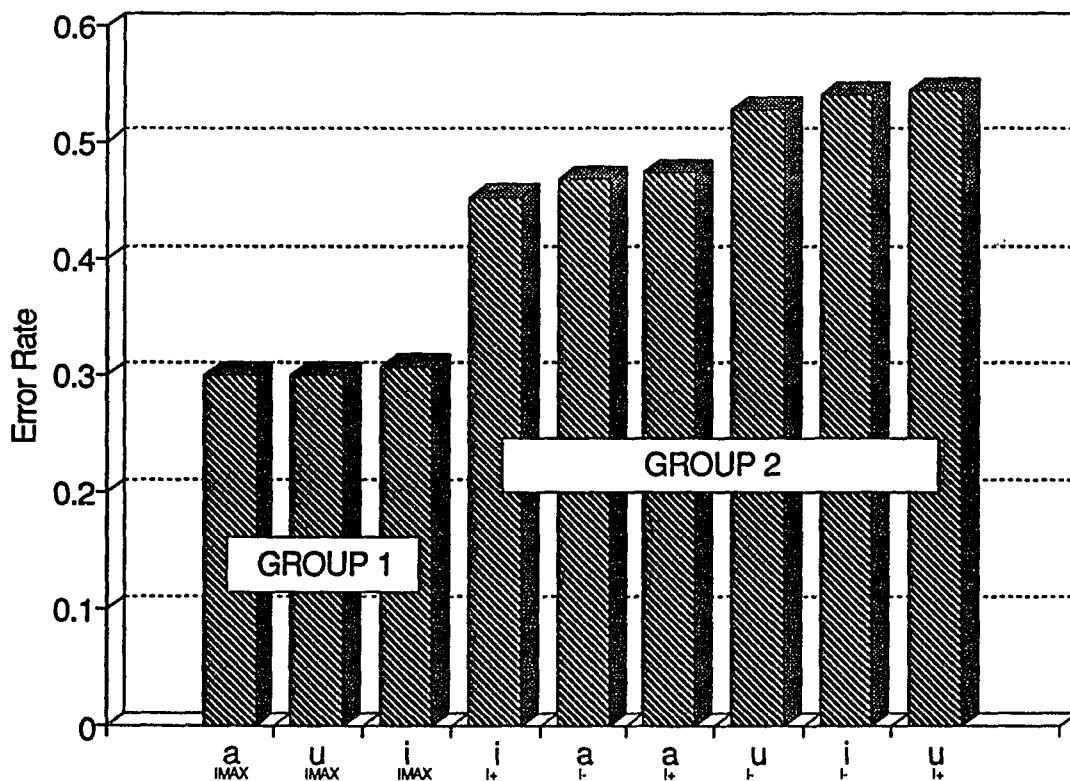


Figure 4.3 Stimulus Level by Vowel Context Interaction for All Consonants

In subsequent discussion, reference is made to consonants which served as the stimuli material. The consonants are represented by the following symbols.

n	as in	run
ng	as in	sang
b	as in	rob
d	as in	feed
g	as in	log
v	as in	have
z	as in	raze
ð	as in	clothe
p	as in	trip
t	as in	wheat
k	as in	flake
f	as in	if
θ	as in	path
s	as in	bus
sh	as in	trash

Figures 4.4 and 4.5 show the minimum at IMAX for individual consonantal errors. In comparing these figures, it can be seen that the voiceless consonants (Figure 4.4) show a wide range of slopes from a relatively shallow valley for /p/ and /s/ to relatively steep slopes for /t/ and /θ/. In contrast, the voiced consonants shown in Figure 4.5 tend to differ little from one another with the exception of a relatively steep slope for /d/.

### Comparison of Error Rates at I- and I+

The focus of this section is the effect of the experimental variables on the observed error rates. The experimental variables were Target Consonant (T), Stimulus Level (L), Vowel Context (V) consisting of /a, i, u/, and Subject (S). The underlying hypothesis of the study was that the pattern of errors at I- and I+

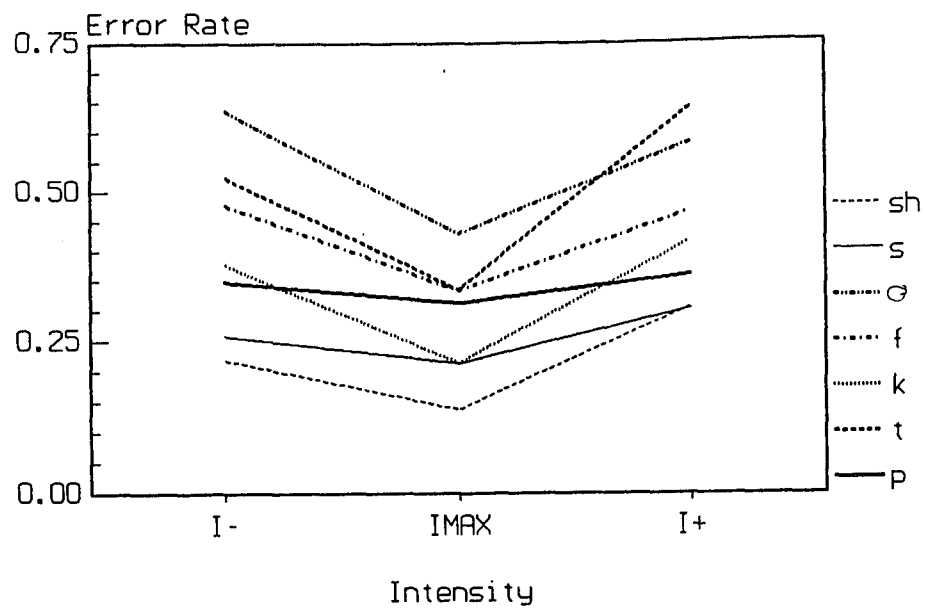


Figure 4.4 Voiceless Consonant Error Rates for Three Stimulus Levels

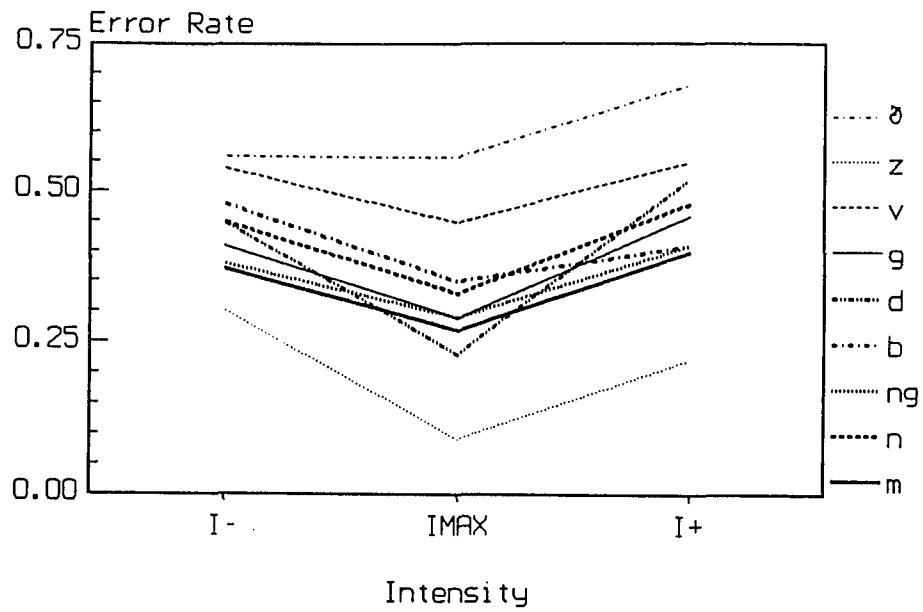


Figure 4.5 Voiced Consonant Error Rates for Three Stimulus Levels

differ significantly although the overall error rate were equal at these two levels. In order to test this hypothesis, it was of interest to compare the error rates as a function of consonant type and vowel context at levels I- and I+. The error rates at IMAX were not included in this analysis as they do not pertain directly to the hypothesis.

#### Error Rates for Voiced Consonants at I- and I+

Table 4.4 shows the confusion matrices as a function of Stimulus Level (I- and I+) and Vowel Context (/a,i,u,/). Each cell represents the number of errors for all ten subjects. The data have been summed over subjects in order to provide a summary of error patterns. Table 4.5 shows the corresponding confusion matrices for the of errors averaged over Subjects. In order to do this, each cell was converted to a proportion by dividing the number of errors by the number of times that the target was presented (for the given intensity level and vowel context). The confusion matrices for individual subjects are presented in Appendix C.

The proportion of errors for each Target Consonant, Stimulus Level, Vowel Context, and Subject were subjected to a repeated measures analysis of variance (ANOVA). The results of the analysis of variance are presented in Table 4.6. The table shows Target Consonant to be a significant effect ( $F=5.8$ ;  $p<.001$ ), as well as Vowel Context ( $F=4.8$ ;  $p=.024$ ). The effect of Stimulus Level was not

Table 4.4 Voiced Consonant Errors for Three Vowel Contexts and Two Stimulus Level Conditions.

VOWEL	LEVEL	TARGET	RESPONSE								TOTAL	
			m	n	ng	b	d	g	v	z		th
a	I-	m	0	11	6	2	0	1	3	0	1	24
		n	6	0	1	0	10	1	1	2	1	22
		ng	8	1	0	0	1	6	1	1	0	18
		b	0	1	1	0	2	5	8	1	3	21
		d	0	2	1	4	0	2	1	5	5	20
		g	0	0	7	4	7	0	1	3	0	22
		v	0	2	1	18	0	13	0	7	3	44
		z	2	5	1	1	1	7	3	0	2	22
		th	2	2	2	8	4	11	5	7	0	41
		TOTAL	18	24	20	37	25	46	23	26	15	234
	I+	m	0	9	3	2	1	1	1	4	2	23
		n	3	0	1	0	6	0	0	1	2	13
		ng	4	6	0	1	0	3	1	3	1	19
		b	2	1	2	0	6	4	3	3	1	22
		d	0	1	1	7	0	6	7	4	8	34
		g	2	1	2	1	11	0	2	3	0	22
		v	5	1	1	15	7	5	0	1	5	40
		z	2	3	3	0	0	4	3	0	0	15
		th	0	2	1	9	9	19	2	10	0	52
TOTAL		18	24	14	35	40	42	19	29	19	240	
i	I-	m	0	9	5	2	2	1	4	3	0	26
		n	10	0	5	2	9	1	3	6	1	37
		ng	7	8	0	1	1	6	2	3	0	28
		b	1	0	2	0	9	11	3	7	1	34
		d	1	3	1	13	0	4	8	2	3	35
		g	0	2	3	7	6	0	6	2	3	29
		v	1	0	0	11	2	8	0	8	3	33
		z	0	2	1	4	2	2	5	0	3	19
		th	0	2	1	10	13	2	6	6	0	40
		TOTAL	20	26	18	50	44	35	37	37	14	281
	I+	m	0	5	7	3	3	2	3	2	1	26
		n	12	0	5	5	4	0	3	3	0	32
		ng	6	9	0	2	0	3	3	5	0	28
		b	2	1	1	0	12	4	6	0	1	27
		d	1	1	1	8	0	9	11	2	4	37
		g	2	3	3	14	14	0	3	1	5	45
		v	1	3	0	6	5	7	0	6	2	30
		z	0	0	1	2	2	1	4	0	5	15
		th	0	2	2	9	9	4	12	3	0	41
TOTAL		24	24	20	49	49	30	45	22	18	281	
u	I-	m	0	6	1	1	4	1	3	2	1	19
		n	16	0	4	2	3	1	1	1	0	28
		ng	14	4	0	1	2	0	4	3	0	28
		b	3	0	1	0	9	11	9	4	2	39
		d	1	1	1	9	0	5	4	6	1	28
		g	2	1	2	11	2	0	3	5	1	27
		v	0	3	0	11	3	5	0	1	5	28
		z	0	0	0	1	2	0	6	0	3	12
		th	1	2	0	8	7	2	10	5	0	35
		TOTAL	37	17	9	44	32	25	40	27	13	244
	I+	m	0	11	2	3	0	1	3	4	1	25
		n	27	0	6	1	7	0	3	5	2	51
		ng	11	7	0	0	2	5	3	4	2	34
		b	6	0	0	0	12	2	9	3	1	33
		d	3	1	2	9	0	10	8	2	1	36
		g	1	2	3	7	4	0	6	3	1	27
		v	4	1	1	11	2	5	0	15	4	43
		z	2	1	1	2	0	0	2	0	1	9
		th	2	0	1	11	3	9	9	10	0	45
TOTAL		56	23	16	44	30	32	43	46	13	303	

Table 4.5 Error Proportions for Voiced Consonants as a Function of Vowel Context and Stimulus Level.

VOWEL	LEVEL	TARGET	RESPONSE									TOTAL	
			m	n	ng	b	d	g	v	z	th		
a	I-	m	0.00	0.17	0.09	0.03	0.00	0.02	0.05	0.00	0.02	0.02	0.37
		n	0.09	0.00	0.02	0.00	0.15	0.02	0.02	0.03	0.02	0.02	0.34
		ng	0.12	0.02	0.00	0.00	0.02	0.09	0.02	0.02	0.02	0.00	0.28
		b	0.00	0.02	0.02	0.00	0.03	0.08	0.13	0.02	0.02	0.05	0.33
		d	0.00	0.03	0.02	0.06	0.00	0.03	0.02	0.08	0.08	0.08	0.31
		g	0.00	0.00	0.10	0.06	0.10	0.00	0.01	0.04	0.00	0.00	0.32
		v	0.00	0.03	0.01	0.26	0.00	0.19	0.00	0.10	0.04	0.04	0.63
		z	0.03	0.08	0.02	0.02	0.02	0.11	0.05	0.00	0.03	0.03	0.33
		th	0.03	0.03	0.03	0.11	0.06	0.15	0.07	0.10	0.00	0.00	0.58
		TOTAL	0.03	0.04	0.03	0.06	0.04	0.08	0.04	0.04	0.03	0.03	0.39
	I+	m	0.00	0.14	0.05	0.03	0.02	0.02	0.02	0.06	0.03	0.03	0.36
		n	0.05	0.00	0.02	0.00	0.09	0.00	0.00	0.02	0.03	0.03	0.20
		ng	0.06	0.09	0.00	0.02	0.00	0.05	0.02	0.05	0.02	0.02	0.29
		b	0.03	0.01	0.03	0.00	0.09	0.06	0.04	0.04	0.01	0.01	0.33
		d	0.00	0.01	0.01	0.10	0.00	0.09	0.10	0.06	0.11	0.11	0.49
		g	0.03	0.01	0.03	0.01	0.16	0.00	0.03	0.04	0.00	0.00	0.33
		v	0.07	0.01	0.01	0.22	0.10	0.07	0.00	0.01	0.07	0.07	0.58
		z	0.03	0.05	0.05	0.00	0.00	0.06	0.05	0.00	0.00	0.00	0.23
		th	0.00	0.03	0.01	0.13	0.13	0.28	0.03	0.14	0.00	0.00	0.75
		TOTAL	0.03	0.04	0.02	0.06	0.07	0.07	0.03	0.05	0.03	0.03	0.40
i	I-	m	0.00	0.13	0.07	0.03	0.03	0.01	0.06	0.04	0.00	0.39	
		n	0.15	0.00	0.07	0.03	0.14	0.01	0.04	0.09	0.01	0.54	
		ng	0.10	0.12	0.00	0.01	0.01	0.09	0.03	0.04	0.00	0.41	
		b	0.02	0.00	0.03	0.00	0.14	0.17	0.05	0.11	0.02	0.52	
		d	0.01	0.04	0.01	0.19	0.00	0.06	0.12	0.03	0.04	0.52	
		g	0.00	0.03	0.05	0.11	0.10	0.00	0.10	0.03	0.05	0.46	
		v	0.02	0.00	0.00	0.17	0.03	0.12	0.00	0.12	0.05	0.50	
		z	0.00	0.03	0.01	0.06	0.03	0.03	0.07	0.00	0.04	0.28	
		th	0.00	0.03	0.01	0.14	0.19	0.03	0.09	0.09	0.00	0.58	
		TOTAL	0.03	0.04	0.03	0.08	0.07	0.06	0.06	0.06	0.02	0.47	
	I+	m	0.00	0.08	0.11	0.05	0.05	0.03	0.05	0.03	0.02	0.40	
		n	0.18	0.00	0.08	0.08	0.06	0.00	0.05	0.05	0.00	0.49	
		ng	0.09	0.14	0.00	0.03	0.00	0.05	0.05	0.08	0.00	0.43	
		b	0.03	0.01	0.01	0.00	0.18	0.06	0.09	0.00	0.01	0.40	
		d	0.01	0.01	0.01	0.12	0.00	0.13	0.16	0.03	0.06	0.54	
		g	0.03	0.04	0.04	0.20	0.20	0.00	0.04	0.01	0.07	0.64	
		v	0.02	0.05	0.00	0.09	0.08	0.11	0.00	0.09	0.03	0.46	
		z	0.00	0.00	0.01	0.03	0.03	0.01	0.06	0.00	0.07	0.22	
		th	0.00	0.03	0.03	0.13	0.13	0.06	0.18	0.04	0.00	0.61	
		TOTAL	0.04	0.04	0.03	0.08	0.08	0.05	0.07	0.04	0.03	0.47	
u	I-	m	0.00	0.09	0.01	0.01	0.06	0.01	0.04	0.03	0.01	0.28	
		n	0.24	0.00	0.06	0.03	0.05	0.02	0.02	0.02	0.00	0.42	
		ng	0.22	0.06	0.00	0.02	0.03	0.00	0.06	0.05	0.00	0.44	
		b	0.04	0.00	0.01	0.00	0.13	0.16	0.13	0.06	0.03	0.57	
		d	0.02	0.02	0.02	0.14	0.00	0.08	0.06	0.09	0.02	0.43	
		g	0.03	0.01	0.03	0.16	0.03	0.00	0.04	0.07	0.01	0.40	
		v	0.00	0.04	0.00	0.16	0.04	0.07	0.00	0.01	0.07	0.41	
		z	0.00	0.00	0.00	0.01	0.03	0.00	0.09	0.00	0.04	0.18	
		th	0.02	0.03	0.00	0.12	0.11	0.03	0.15	0.08	0.00	0.53	
		TOTAL	0.06	0.03	0.02	0.07	0.05	0.04	0.07	0.05	0.02	0.41	
	I+	m	0.00	0.17	0.03	0.05	0.00	0.02	0.05	0.06	0.02	0.39	
		n	0.40	0.00	0.09	0.01	0.10	0.00	0.04	0.07	0.03	0.75	
		ng	0.17	0.11	0.00	0.00	0.03	0.08	0.05	0.06	0.03	0.52	
		b	0.09	0.00	0.00	0.00	0.18	0.03	0.13	0.04	0.01	0.49	
		d	0.05	0.02	0.03	0.14	0.00	0.15	0.12	0.03	0.02	0.55	
		g	0.01	0.03	0.04	0.10	0.06	0.00	0.09	0.04	0.01	0.40	
		v	0.06	0.01	0.01	0.16	0.03	0.07	0.00	0.22	0.06	0.62	
		z	0.03	0.01	0.01	0.03	0.00	0.00	0.03	0.00	0.01	0.13	
		th	0.03	0.00	0.02	0.17	0.05	0.14	0.14	0.15	0.00	0.68	
		TOTAL	0.09	0.04	0.03	0.07	0.05	0.05	0.07	0.08	0.02	0.50	

Table 4.6 Summary Table of Analysis of Variance for Voiced Consonant Errors (T=Target Consonant; L=Stimulus Level; V=Vowel Context; S=Subject).

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	SIGNIF. LEVEL
T	25.363	8	3.170	5.806	0.001
L	0.380	1	0.380	3.022	0.114
V	4.695	2	2.348	4.801	0.021
T x L	2.405	8	0.300	1.336	0.239
T x V	10.654	16	0.666	2.198	0.008
L x V	0.498	2	0.249	0.832	0.545
T x L x V	3.708	16	0.232	1.167	0.301
S	15.245	9	1.694		
T x S	39.317	72	0.548		
L x S	1.131	9	0.126		
V x S	8.802	18	0.489		
T x L x S	16.166	72	0.225		
T x V x S	43.624	144	0.303		
L x V x S	5.334	18	0.299		
T x L x V x S	28.600	144	0.197		
TOTAL	205.956	539			

statistically significant ( $p=.114$ ). This latter result supports the earlier observation that the differences in error rates at I- and I+ were not statistically significant.

A post-hoc analysis (Tukey HSD) of the Target Consonant effect showed the formation of three groups consisting of the consonants / $\delta$ ,v,d,n,b,g,ng/, /v,d,n,b,g,ng,m/, and /d,n,b,g,ng,m,z/ respectively. As previously stated, the error rates for the consonants within each group do not differ significantly from each other while the error rates for consonants in separate groups differ significantly. For example, / $\delta$ / does not fall into the same group with either /m/ or /z/, indicating that the error rate for / $\delta$ / is significantly different from that for either /m/ or /z/. Similarly, the error rate for /v/ is significantly different from that for /z/.

Figure 4.6 shows the ordering of the consonants in terms of error rate. Note that the two highest error rates are associated with fricative consonants, (i.e., /v, $\delta$ /). The stop consonants tend to make up the middle of the range while the nasals fall towards the end of the lower range. In contrast to the fricatives /v, $\delta$ /, which have relatively high error rates, the fricative /z/ has the lowest error rate.

The post hoc analysis of the Vowel Context effect showed that mean error rates could be assigned to two groups. One group consisted of /a,i/ while the other consisted of /i,u/. These data indicate that the error rate for /u/ is significantly higher than that for /a/. Figure 4.7 shows mean error rates for the three vowels plotted as a function of Stimulus Level. This figure shows that for Vowel Context /i/ and /a/, the error rate remains relatively constant for the two

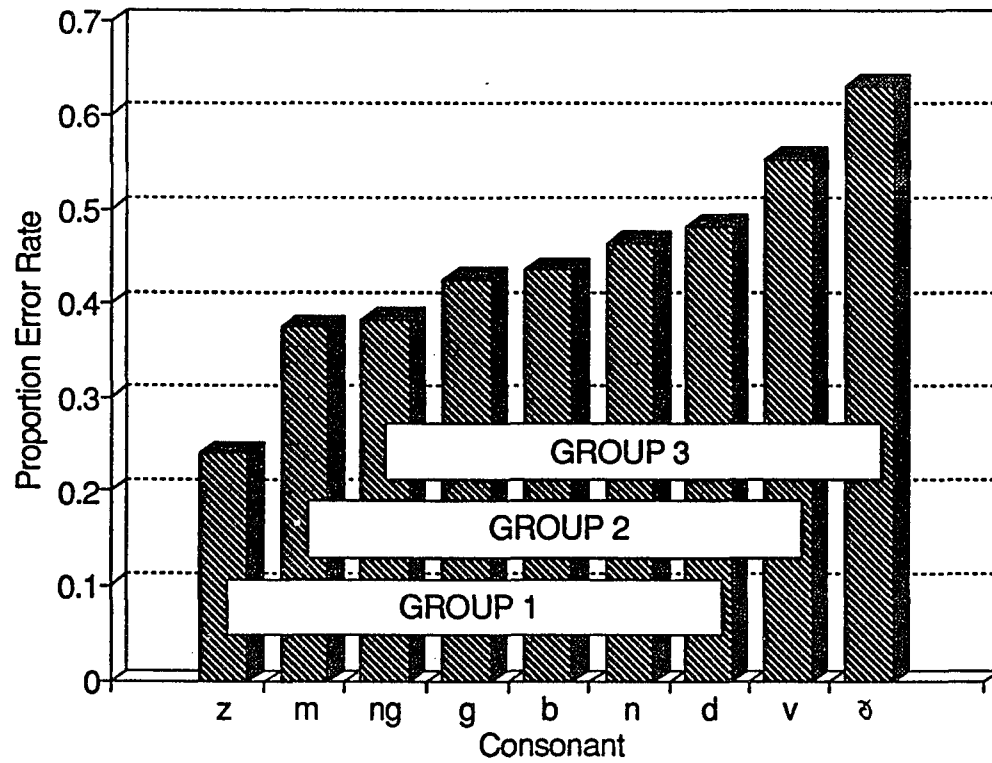


Figure 4.6 Post-Hoc Analysis of Voiced Consonant Error Rate; Error rates for consonants within a group do not differ significantly from one another.

Stimulus Level conditions, but for Vowel Context /u/, there is an increase in error rate for I+ compared to I-.

While not treated statistically, the performance of the subjects is presented in Figure 4.8.

Table 4.6 shows that none of the higher order interactions that include Stimulus Level was significant. In contrast, all two- and three-way interactions that do not include Stimulus Level were found to be significant.

#### Grouping by Manner of Articulation: Voiced Consonants

A common technique in analyses of this type is to group the speech sounds according to their articulatory characteristics. By so doing, the variability of the data may be reduced thereby increasing the statistical power of the subsequent analysis.

Examination of Figure 4.6 shows that the consonants appear to be grouped approximately according to manner of articulation with one notable exception. Specifically, the error rates for the nasal consonants are relatively low, on the average, while those for the stop consonants are higher, on the average. The results of the fricative consonants are not categorized as easily. Two of the fricatives have high error rates (/ð,v/), while the third fricative, /z/, has the lowest error rate. The data were re-analyzed by grouping the data by manner of

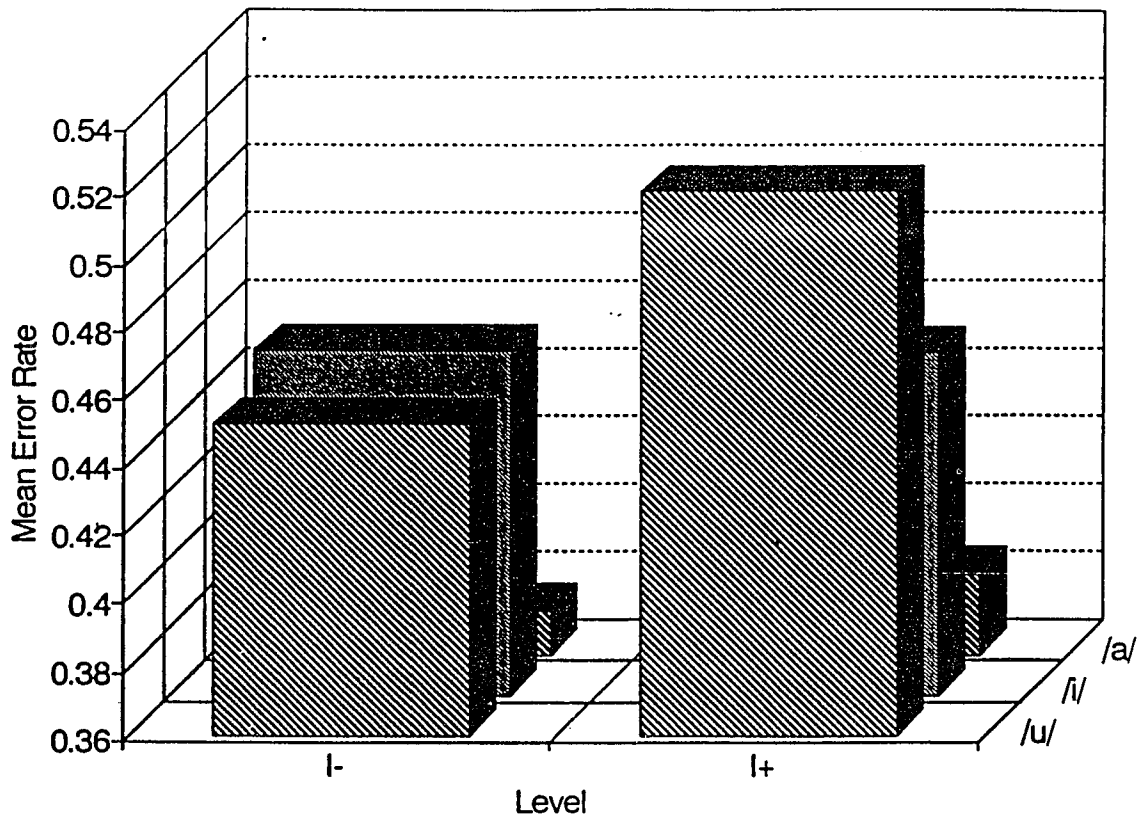


Figure 4.7 Vowel Context Error Rates for Voiced Consonants

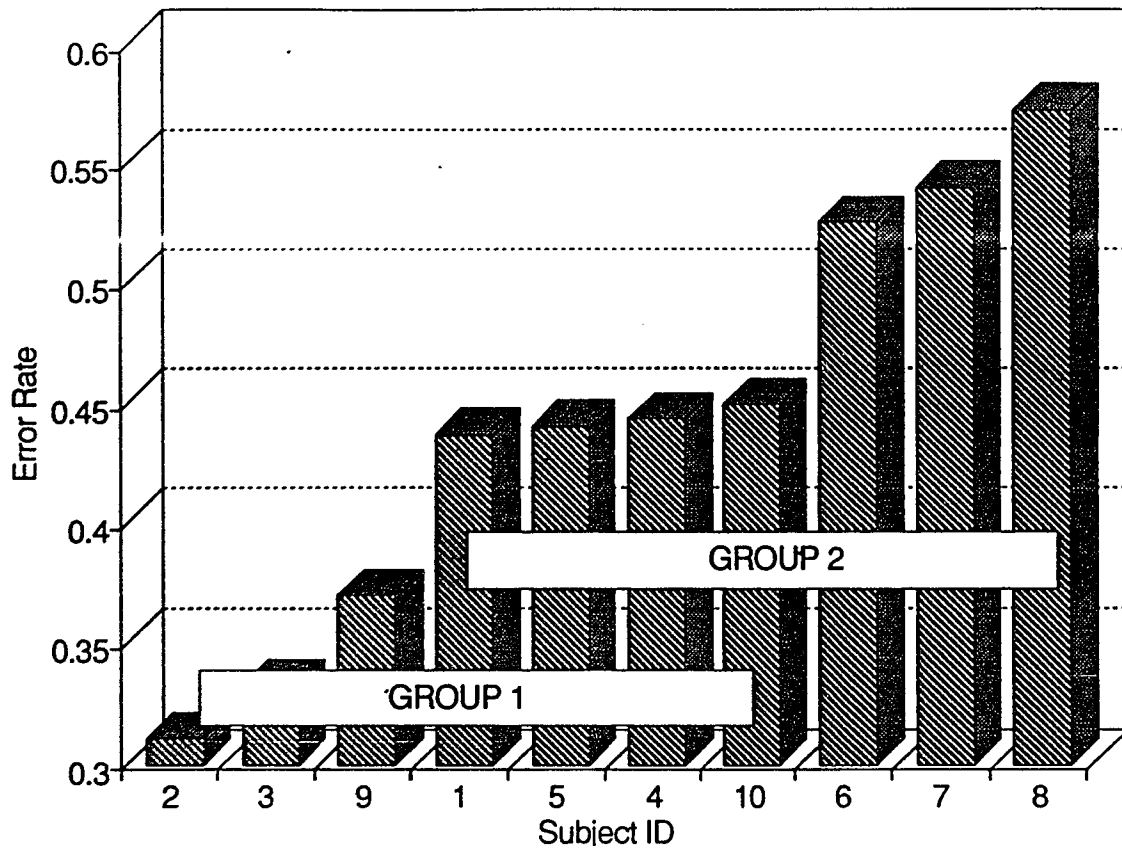


Figure 4.8 Subject Effect for Voiced Consonants

articulation (stop, fricative<sup>2</sup>, nasal) and subjecting the grouped data to a repeated measures analysis of variance. The result of this analysis is presented in Table 4.7. In this analysis, the symbol T refers to the Target Manner of Articulation (stop, nasal, or fricative).

As shown in Table 4.7, of the three main effects Target, Stimulus Level, and Vowel Context, only the Vowel Context ( $F=5.2$ ;  $p=.017$ ) is significant. Again Vowel Context /u/ had the highest error rate and a post hoc analysis showed the error rate for /u/ to be significantly higher than for /a/.

The analysis of variance also showed a significant interaction of Target Consonant by Vowel ( $F=4.5$ ;  $p=.005$ ). A post hoc analysis showed that the Target Consonant by Vowel Context interaction reflects a significantly higher error rate for nasals in a Vowel Context of /u/ than for nasals paired with /a/. This analysis also indicated that stops in a Vowel Context of /i/ are significantly higher than the nasals in an /a/ context.

The finding most relevant to the underlying hypothesis regarding error patterns at I- and I+ is the three-way interaction of Target by Stimulus Level by Vowel Context which approached a significant level ( $T \times L \times V$ ;  $F=2.2$ ;  $p=.088$ ). Because the probability level borders on significance, the possibility exists that

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<sup>2</sup> An alternative method of grouping the data would have been to form two fricative groups, fricatives of low acoustic power (/θ/ and /v/) and fricatives of high acoustic power(/z/). This grouping would have provided a more distinct hierarchical ordering of the consonant groups, but since this alternative grouping is derived from a post hoc analysis, the statistical significance levels of the subsequent analysis would be suspect.

a subgroup of the subjects may have shown a significant three-way interaction involving Target, Stimulus Level, and Vowel Context. Individual analyses of variance were computed for each subject and the subjects were then ranked in descending order of magnitude for the LV interaction term for each of the three consonant groups. Subjects showing the largest interaction terms were subjects 3, 4, 5, and 6. Figure 4.10 shows the Target Consonant by Stimulus Level by Vowel Context interaction for the combined data of subjects 3, 4, 5, and 6. As can be seen, the stops show very little Stimulus Level effect while the nasals show the largest effect, particularly within a Vowel Context of /u/.

In the process of grouping the by manner of articulation it was observed that, on average, there were more errors within a manner category than across a manner boundary. For example, a stop consonant was typically confused with another stop consonant rather than by a nasal or a fricative consonant. In order to test the significance of this observation, the data were re-analyzed with a five-way repeated measures analysis of variance (repeated over Subjects) in which the factor Within/Between Manner Confusions was included along with Target Consonant, Stimulus Level, Vowel Context, and Subject. The results of this analysis are summarized in Table 4.8. In the table, W is used to represent the factor of Within/Between Manner Confusions. The significant main effects include Within/Between Manner Confusions ( $F=16.9$ ;  $p=.003$ ) and Vowel Context ( $F=9.3$ ;  $p=.002$ ). The Within Manner confusions were significantly higher than Between Manner confusions. The effect of Vowel Context was the same as that

Table 4.7 Summary Table of Analysis of Variance for Voiced Consonants  
 Grouped by Manner of Articulation (T=Target Consonant Manner; V=Vowel  
 Context; L=Stimulus Level; S=Subject).

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	SIGNIF. LEVEL
T	0.554	2	0.277	2.284	0.129
L	0.125	1	0.125	3.105	0.109
V	1.729	2	0.864	5.146	0.017
T x V	2.221	4	0.555	4.472	0.005
L x V	0.139	2	0.070	0.747	0.508
T x L	0.011	2	0.005	0.174	0.842
T x L x V	0.399	4	0.100	2.198	0.088
S	4.797	9	0.533		
T x S	2.184	18	0.121		
L x S	0.362	9	0.040		
V x S	3.023	18	0.168		
T x L x S	0.551	18	0.031		
T x V x S	4.470	36	0.124		
L x V x S	1.675	18	0.093		
T x L x V x S	1.633	36	0.045		
TOTAL	23.873	179			

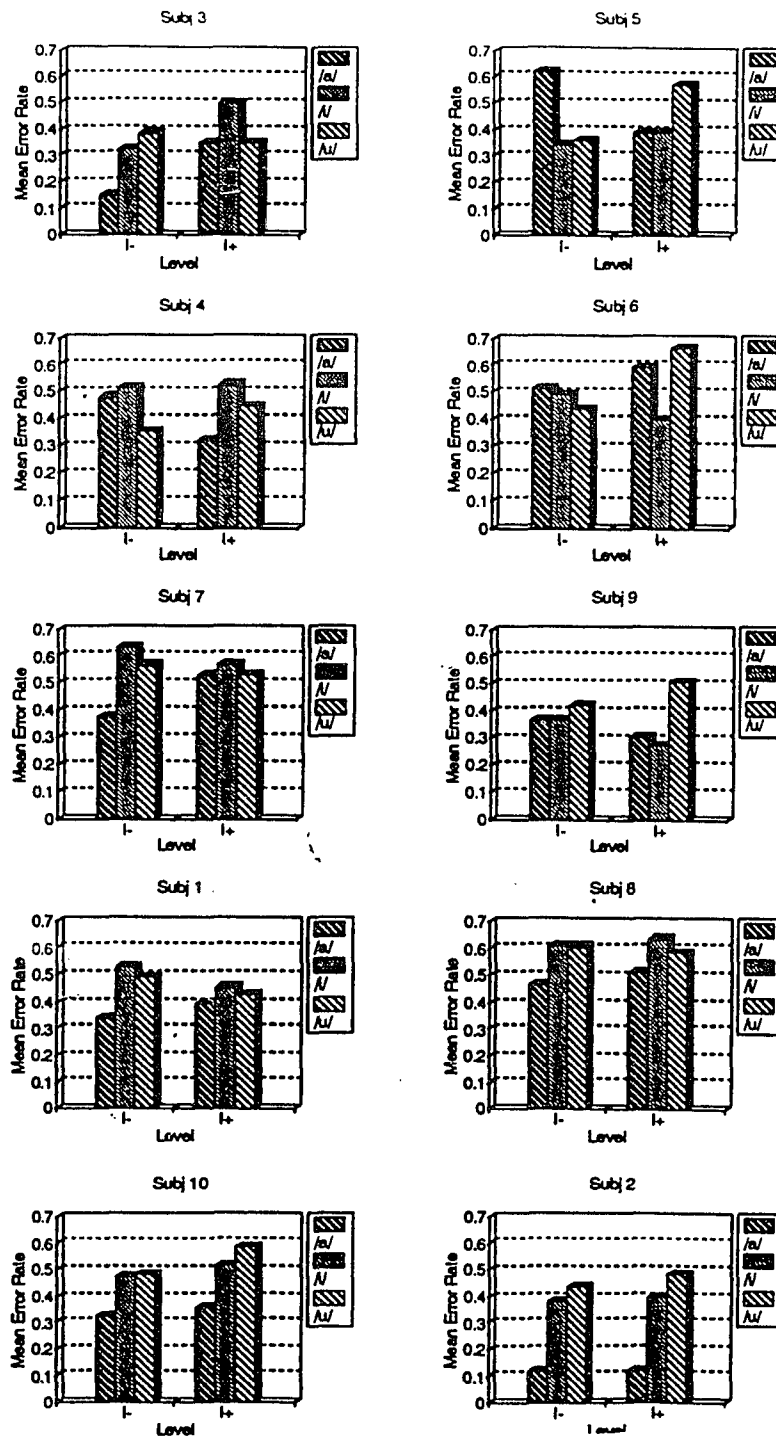


Figure 4.9 Stimulus Level by Vowel Context by Subject Interaction for Voiced Consonants

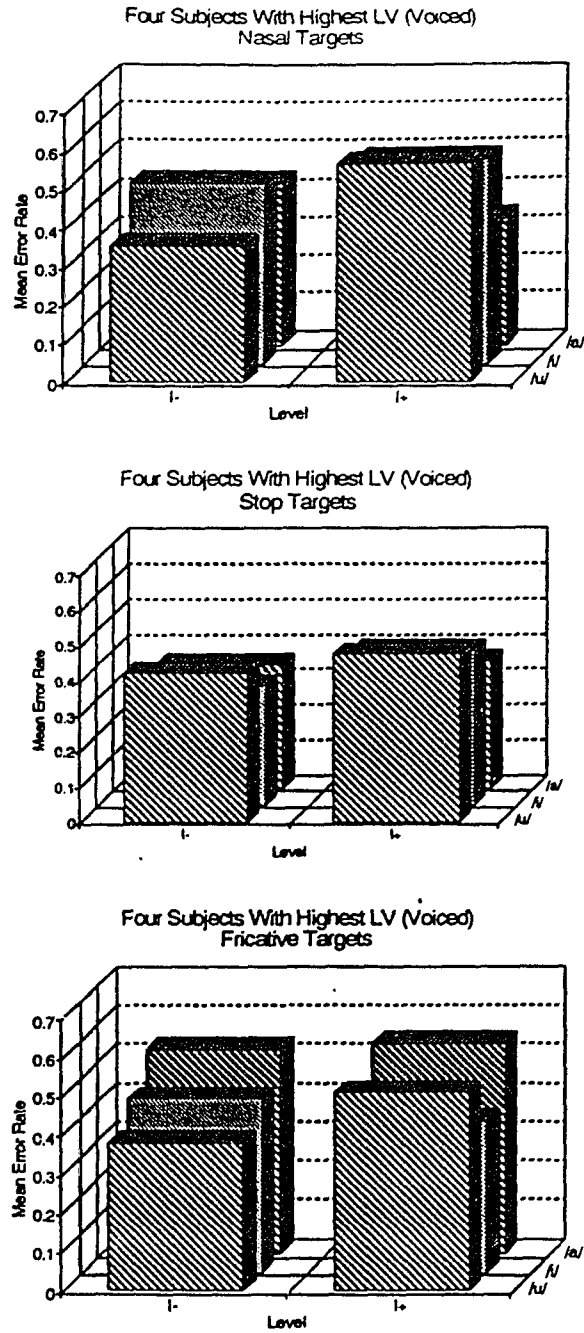


Figure 4.10 Stimulus Level by Vowel Context Interaction as a Function of Target Consonant for Voiced Consonants Grouped by Manner of Articulation

observed in the previous analysis. The two-way interaction of Within/Between Manner Confusions by Vowel Context was significant ( $F=3.6$ ;  $p=.049$ ). The post hoc analysis showed that the data could be subdivided into two groups, in which the error rate for the Within Manner category in a context of /i/ being significantly higher than the Between Manner category for all three Vowel Contexts.

Two significant three-way interactions were observed. These were Target Consonant by Stimulus Level by Vowel Context ( $F=3.3$ ;  $p=.021$ ), and Within/Between Manner Confusions by Stimulus Level by Vowel Context ( $F=4.8$ ;  $p=.022$ ). Both of these three-way interactions, involving Stimulus Level are relevant to the underlying hypothesis of the study. The Target Manner by Stimulus Level by Vowel Context interaction was the same as that observed in the previous analysis and has already been described. A Tukey HSD post hoc analysis was thus performed on the Within/Between Manner Confusions by Stimulus Level by Vowel Context interaction. The results, as summarized in Figure 4.11, can be subdivided into four groups with considerable overlap among groups. The most striking aspect of the post hoc analysis is that the difference between the Within and Between Manner error rates is relatively small for the Vowel Context /i/ (for both I- and I+) and for Vowel Context /u/ for the I+ Level only. The difference in error rates is relatively small for Vowel Context /a/ (for both I- and I+). For the remaining condition, Vowel Context /u/ at I-, the difference in error rates is reversed.

Table 4.8 Summary Table of Analysis of Variance for Voiced Consonants Grouped By Manner of Articulation (L=Stimulus Level; V=Vowel Context; S=Subject; T=Target Consonant Manner; W=Within/Between Manner).

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	SIGNIF. LEVEL
With/Out	0.633	1	0.6327	16.862	0.003
Target	0.021	2	0.010	1.086	0.360
Level	0.030	1	0.030	4.518	0.060
Vowel	0.119	2	0.060	9.280	0.002
W x T	0.250	2	0.125	2.330	0.125
W x L	0.080	1	0.080	1.773	0.214
T x L	0.017	2	0.009	2.481	0.110
W x V	0.143	2	0.072	3.561	0.049
T x V	0.135	4	0.034	2.458	0.062
L x V	0.075	2	0.037	2.890	0.080
W x T x L	0.040	2	0.020	1.425	0.266
W x T x V	0.098	4	0.025	1.916	0.128
W x L x V	0.165	2	0.082	4.745	0.022
T x L x V	0.069	4	0.017	3.307	0.021
W x T x L x V	0.050	4	0.012	1.171	0.340
Subject	0.017	9	0.018		
W x S	0.338	9	0.038		
T x S	0.172	18	0.010		
L x S	0.059	9	0.007		
V x S	0.116	18	0.006		
W x T x S	0.964	18	0.054		
W x L x S	0.405	9	0.045		
T x L x S	0.060	18	0.003		
W x V x S	0.362	18	0.020		
T x V x S	0.494	36	0.014		
L x V x S	0.233	18	0.013		
W x T x L x S	0.254	18	0.014		
W x T x V x S	0.461	36	0.013		
W x L x V x S	0.313	18	0.017		
T x L x V x S	0.188	36	0.005		
W x T x L x V x S	0.381	36	0.011		
TOTAL	6.888	359			

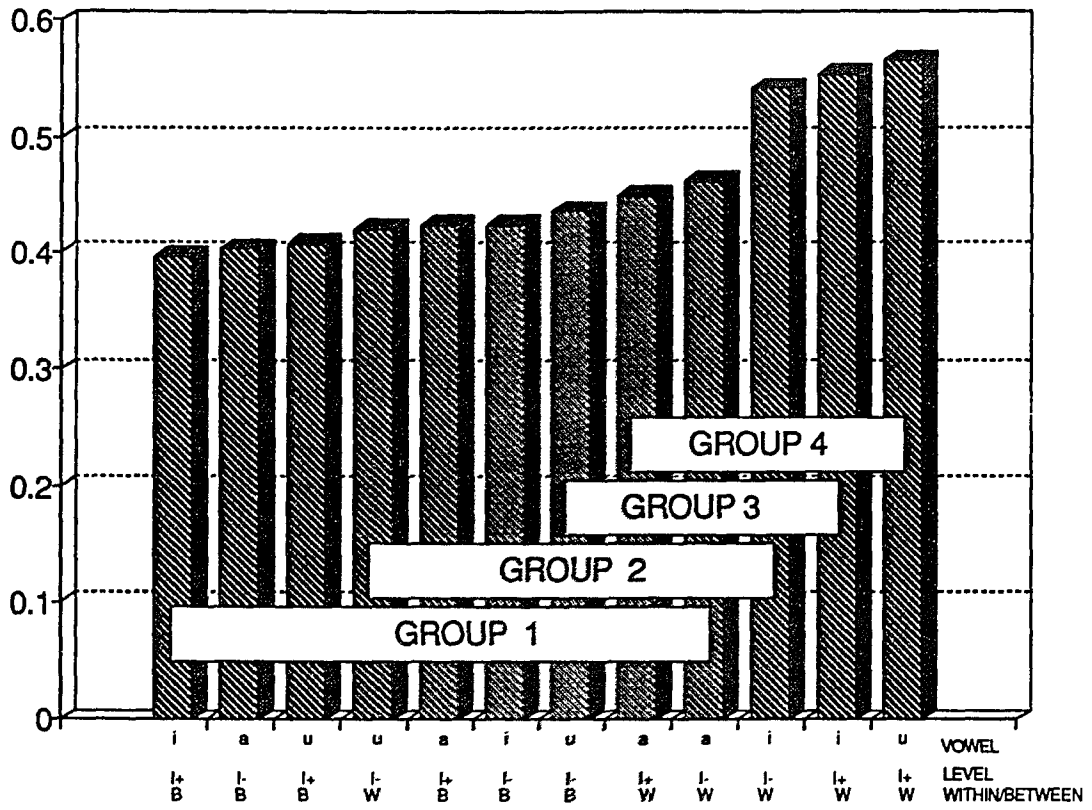


Figure 4.11 Within / Between Manner Confusions as a Function of Stimulus Level and Vowel Context

### Error Rates for Voiceless Consonants at I- and I+

The data for the voiceless consonants were analyzed in much the same way as the voiced consonants. Table 4.9 shows the confusion matrix for voiceless consonants with each cell representing the absolute number of errors. As with the voiced consonant data, each cell was converted to an error proportion. The result of this conversion is displayed in Table 4.10.

An analysis of variance was performed on the percent error scores for each consonant under each experimental condition (Stimulus Level and Vowel Context environment). As before, an inverse sine transformation was used to stabilize the error variance. The results are summarized in Table 4.11 where it can be seen that significant effects are Target Consonant ( $F=9.0$ ;  $p<.001$ ), and Vowel Context ( $F=3.9$ ;  $p=.039$ ). Stimulus Level was not significant. A significant interaction is noted between Target Consonant and Vowel Context. A post hoc analysis of the Target Consonant effect was administered with the result that three groups were formed, these being / $\theta, t, f, k$ /, / $t, f, k, p$ /, and / $f, k, p, s, sh$ /. Items within a group did not differ significantly from each other in terms of error rate. Figure 4.12 shows the mean error rates for the voiceless consonants. It should be noted that mean error rates for / $sh$ / and / $s$ / are the lowest and differ significantly from those of / $t$ / and / $\theta$ / which represent the highest error rates.

A post hoc analysis focusing on the mean error rate for Vowel Context

Table 4.9 Voiceless Consonant Error Matrix for Two Stimulus Level Conditions and Three Vowel Contexts.

VOWEL	LEVEL	TARGET	RESPONSE						TOTAL	
			p	t	k	f	th	s		sh
a	I-	p	0	8	6	3	2	1	3	23
		t	10	0	10	5	16	6	1	48
		k	4	6	0	7	5	2	1	25
		f	15	4	2	0	8	4	1	34
		th	14	12	10	12	0	1	2	51
		s	5	3	2	4	3	0	4	21
		sh	1	1	0	4	3	7	0	16
	TOTAL	49	34	30	35	37	21	12	218	
	I+	p	0	6	4	6	3	1	3	23
		t	23	0	16	3	16	1	2	61
		k	6	7	0	9	5	1	4	32
		f	13	4	4	0	7	2	1	31
		th	8	13	4	12	0	10	0	47
		s	6	1	0	3	0	0	12	22
sh		1	3	2	1	7	4	0	18	
TOTAL	57	34	30	34	38	19	22	234		
i	I-	p	0	6	9	5	2	2	3	27
		t	9	0	8	2	14	1	1	35
		k	2	7	0	1	5	2	1	18
		f	11	4	7	0	9	2	1	34
		th	2	19	8	8	0	2	6	45
		s	2	4	2	2	2	0	7	19
		sh	0	0	3	3	5	2	0	13
	TOTAL	26	40	37	21	37	11	19	191	
	I+	p	0	12	9	3	4	1	0	29
		t	8	0	4	2	15	1	0	30
		k	8	4	0	2	2	1	0	17
		f	8	8	7	0	7	2	2	34
		th	3	13	11	7	0	0	4	38
		s	0	1	3	0	4	0	4	12
sh		1	3	2	4	3	7	0	20	
TOTAL	28	41	36	18	35	12	10	180		
u	I-	p	0	9	3	6	3	1	1	23
		t	11	0	5	4	10	0	2	32
		k	14	6	0	9	4	3	1	37
		f	9	2	6	0	8	1	3	29
		th	6	6	4	15	0	1	4	36
		s	1	0	1	11	3	0	3	19
		sh	4	1	1	5	6	2	0	19
	TOTAL	45	24	20	50	34	8	14	195	
	I+	p	0	6	5	3	6	1	3	24
		t	11	0	14	3	11	2	1	42
		k	14	3	0	16	5	1	2	41
		f	13	4	2	0	8	2	1	30
		th	5	9	2	12	0	3	3	34
		s	4	3	2	3	6	0	14	32
sh		2	1	3	13	6	5	0	30	
TOTAL	49	26	28	50	42	14	24	233		

Table 4.10 Proportion of Errors for Voiceless Consonants for Two Stimulus Level Conditions and Three Vowel Contexts.

VOWEL	LEVEL	TARGET	RESPONSE							TOTAL
			p	t	k	f	th	s	sh	
a	I-	p	0.00	0.12	0.09	0.04	0.03	0.01	0.04	0.33
		t	0.14	0.00	0.14	0.07	0.22	0.08	0.01	0.66
		k	0.06	0.09	0.00	0.10	0.07	0.03	0.01	0.37
		f	0.22	0.06	0.03	0.00	0.12	0.06	0.01	0.49
		th	0.20	0.17	0.14	0.17	0.00	0.01	0.03	0.74
		s	0.08	0.05	0.03	0.06	0.05	0.00	0.06	0.32
		sh	0.02	0.02	0.00	0.06	0.05	0.11	0.00	0.24
	TOTAL	0.10	0.07	0.06	0.07	0.08	0.04	0.03	0.45	
	I+	p	0.00	0.09	0.06	0.09	0.04	0.01	0.04	0.34
		t	0.32	0.00	0.23	0.04	0.23	0.01	0.03	0.86
		k	0.09	0.10	0.00	0.13	0.07	0.01	0.06	0.46
		f	0.19	0.06	0.06	0.00	0.10	0.03	0.01	0.46
		th	0.11	0.19	0.06	0.17	0.00	0.14	0.00	0.67
		s	0.09	0.01	0.00	0.04	0.00	0.00	0.18	0.33
sh		0.01	0.04	0.03	0.01	0.10	0.06	0.00	0.26	
TOTAL	0.12	0.07	0.06	0.07	0.08	0.04	0.05	0.48		
i	I-	p	0.00	0.09	0.13	0.07	0.03	0.03	0.04	0.40
		t	0.13	0.00	0.12	0.03	0.21	0.01	0.01	0.51
		k	0.03	0.10	0.00	0.01	0.07	0.03	0.01	0.26
		f	0.16	0.06	0.10	0.00	0.13	0.03	0.01	0.50
		th	0.03	0.26	0.11	0.11	0.00	0.03	0.08	0.63
		s	0.03	0.06	0.03	0.03	0.03	0.00	0.10	0.28
		sh	0.00	0.00	0.04	0.04	0.07	0.03	0.00	0.19
	TOTAL	0.05	0.08	0.08	0.04	0.08	0.02	0.04	0.40	
	I+	p	0.00	0.17	0.13	0.04	0.06	0.01	0.00	0.41
		t	0.12	0.00	0.06	0.03	0.22	0.01	0.00	0.44
		k	0.11	0.06	0.00	0.03	0.03	0.01	0.00	0.24
		f	0.12	0.12	0.11	0.00	0.11	0.03	0.03	0.52
		th	0.04	0.19	0.16	0.10	0.00	0.00	0.06	0.54
		s	0.00	0.01	0.04	0.00	0.06	0.00	0.06	0.17
sh		0.01	0.04	0.03	0.06	0.04	0.10	0.00	0.30	
TOTAL	0.06	0.08	0.07	0.04	0.07	0.03	0.02	0.38		
u	I-	p	0.00	0.13	0.04	0.09	0.04	0.01	0.01	0.33
		t	0.16	0.00	0.07	0.06	0.14	0.00	0.03	0.46
		k	0.21	0.09	0.00	0.13	0.06	0.04	0.01	0.54
		f	0.14	0.03	0.09	0.00	0.12	0.02	0.05	0.44
		th	0.09	0.09	0.06	0.21	0.00	0.01	0.06	0.51
		s	0.01	0.00	0.01	0.16	0.04	0.00	0.04	0.27
		sh	0.06	0.01	0.01	0.07	0.09	0.03	0.00	0.28
	TOTAL	0.09	0.05	0.04	0.10	0.07	0.02	0.03	0.41	
	I+	p	0.00	0.09	0.07	0.04	0.09	0.01	0.04	0.36
		t	0.16	0.00	0.20	0.04	0.16	0.03	0.01	0.61
		k	0.20	0.04	0.00	0.23	0.07	0.01	0.03	0.58
		f	0.19	0.06	0.03	0.00	0.12	0.03	0.01	0.43
		th	0.07	0.13	0.03	0.18	0.00	0.04	0.04	0.51
		s	0.06	0.04	0.03	0.04	0.09	0.00	0.21	0.47
sh		0.03	0.01	0.04	0.19	0.09	0.07	0.00	0.43	
TOTAL	0.10	0.05	0.06	0.10	0.09	0.03	0.05	0.48		

Table 4.11 Summary Table of Analysis of Variance for Voiceless Consonants  
(T=Target Consonant; L=Stimulus Level; V=Vowel Context; S=Subject).

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	SIGNIF. LEVEL
T	27.457	6	4.576	9.002	0.001
L	0.334	1	0.334	2.660	0.135
V	2.277	2	1.139	3.919	0.038
T x L	1.291	6	0.215	1.023	0.421
T x V	8.836	12	0.736	4.101	0.001
L x V	0.583	2	0.292	1.733	0.204
T x L x V	1.870	12	0.156	0.864	0.586
S	7.867	9	0.874		
T x S	27.452	54	0.508		
L x S	1.131	9	0.126		
V x S	5.230	18	0.291		
T x L x S	11.359	54	0.210		
T x V x S	19.391	108	0.180		
L x V x S	3.030	18	0.168		
T x L x V x S	19.473	108	0.180		
TOTAL	205.956	419			

indicated that error rates for Vowel Context /a/ and /u/ were significantly different from /i/, but not each other.

An inspection of Figure 4.12 shows that the mean error rates for voiceless consonants form a continuum consistent with the acoustic energy, or strength, of the consonants. Specifically, the acoustically less powerful consonants (/f, k, t, θ/) show higher error rates than do the acoustically more powerful consonants (/s, sh/). In order to evaluate the significance of this apparent pattern, consonants were divided into a strong (/s, sh, p/) and weak (/t, k, f, θ/) group and subjected to an analysis of variance. The grouping was based upon data presented by Fletcher (1953). The summary table of the analysis of variance is presented in Table 4.12. The main effect of Acoustic Energy (A) was significant ( $F=51.2$ ;  $p=.001$ ). In addition, the Stimulus Level by Vowel Context interaction was significant ( $F=10.6$ ;  $p=.001$ ). The three-way interaction Acoustic Strength by Stimulus Level by Vowel Context bordered on significance with an associated probability equal to .051. A post hoc analysis confirmed that the weak consonants had a significantly higher mean error rate than did the strong consonants. A post hoc analysis of the Stimulus Level by Vowel Context interaction resulted in the formation of two groups. As with previous results, an increase in error rate is found in the Vowel Context of /u / when Stimulus Level is I+ (Figure 4.13). Figure 4.14 shows the interaction of Strength x Stimulus Level x Vowel Context. It can be seen that the Vowel Context of both /a/ and /i/ showed no change or a decrease in error rate when Stimulus Level is increased. In marked contrast,

error rate increases with Stimulus Level in a Vowel Context of /u/. Furthermore, the increase is greater for the weak consonants.

The voiceless data were grouped by manner of articulation into Stops (/p,t,k/) and Fricatives (/f,θ,s,sh/). The only significant effect to emerge from this analysis was the main effect of Vowel Context ( $F=3.84$ ;  $p=.04$ ). No higher order interactions were significant.

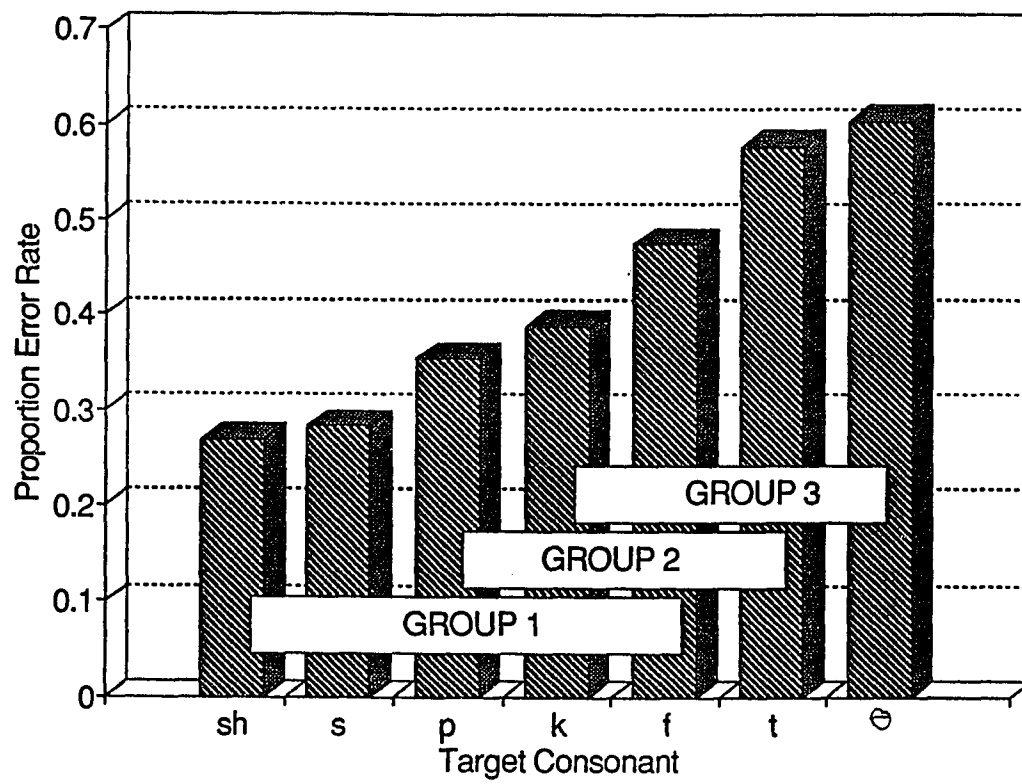


Figure 4.12 Voiceless Consonant Error Rates

Table 4.12 Summary Table of Analysis of Variance for Voiceless Consonants  
(A=Acoustic Energy; L=Stimulus Level; V=Vowel Context; S=Subject).

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES	F RATIO	SIGNIF. LEVEL
A	4.686	1	4.686	51.226	0.001
L	0.004	1	0.004	0.062	0.803
V	0.523	2	0.262	2.520	0.107
A x L	0.002	1	0.002	0.056	0.813
A x V	0.046	2	0.023	0.493	0.624
L x V	1.304	2	0.652	10.646	0.001
A x L x V	0.543	2	0.271	3.494	0.050
S	1.686	9	0.187		
A x S	0.823	9	0.091		
L x S	0.508	9	0.056		
V x S	1.868	18	0.104		
A x L x S	0.380	9	0.042		
A x V x S	0.844	18	0.047		
L x V x S	1.103	18	0.061		
A x L x V x S	1.398	18	0.078		
TOTAL	15.719	119			

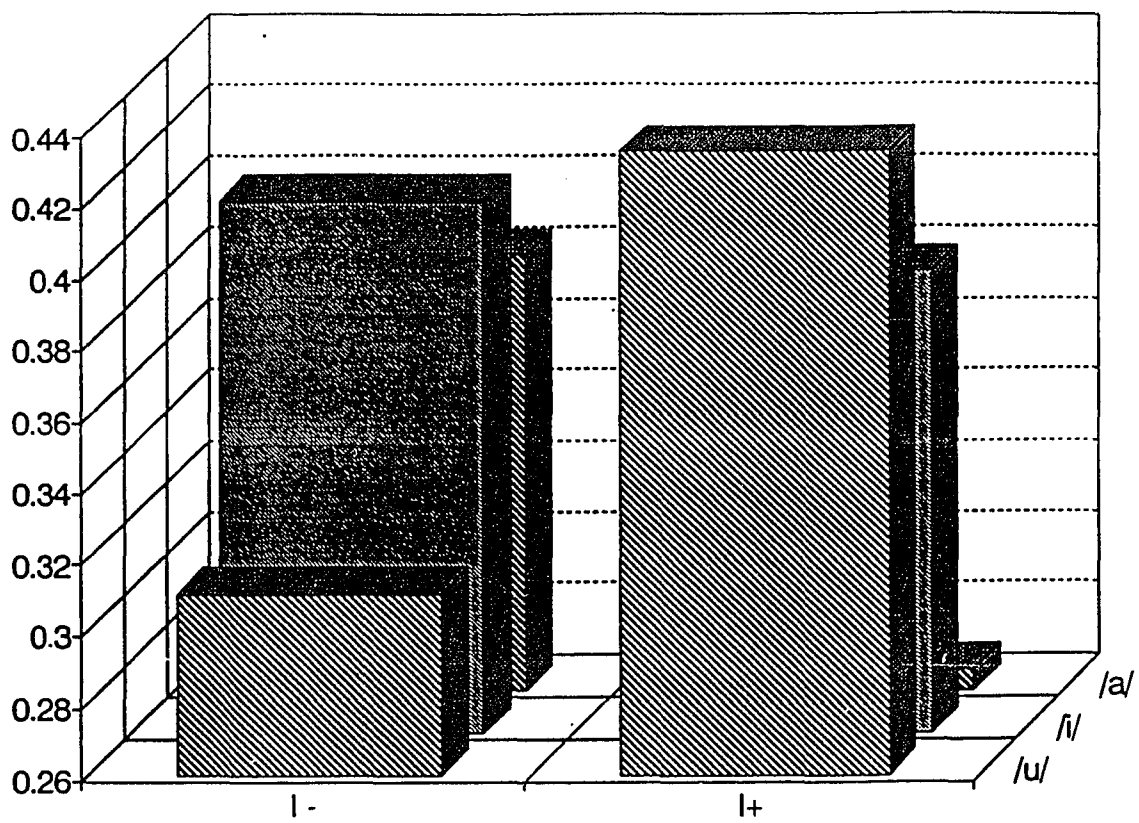


Figure 4.13 Stimulus Level by Vowel Context Interaction for Voiceless Consonants

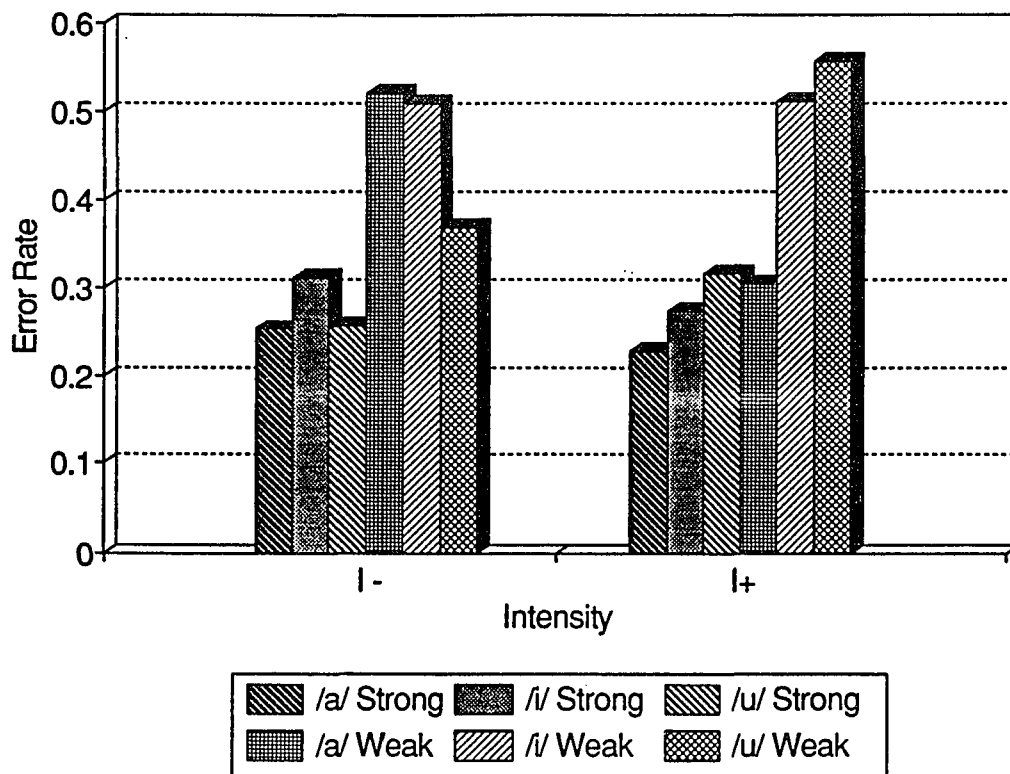


Figure 4.14 Stimulus Level by Vowel Context by Acoustic Strength Interaction for Voiceless Consonants

## ERROR PATTERNS AT I- AND I+

### Introduction

A powerful method for analyzing confusion matrices is that of log linear analysis (Bell et al, 1986). A useful property of log linear analysis is that simple additive models of the data can be developed efficiently and with high statistical precision in a manner analogous to the modeling of fixed effects in an analysis of variance. It should be noted, however, that a number of different models may provide an adequate fit to the data.

In discussing log linear analysis, the nomenclature suggested by Bishop (1977) and Bell et al (1986) will be used. A single uppercase letter is used to signify a simple effect such as T for Target Consonant, R for Response, L for Stimulus Level, and V for Vowel Context. A two-letter combination refers to a two-way interaction, such as RT for the interaction of Response and Target Consonant. A three-letter group represents a three-way interaction (e.g., RTL is the interaction of Response, Target Consonant and Stimulus Level). When the model consists of two or more additive effects, a comma is used to separate the symbols representing these effects; e.g. RT, L denotes the model comprised of the two way interaction of Response and Target Consonant plus the Stimulus Level effect.

Prior to performing the log linear analysis, it was necessary to collapse the error matrices over at least one variable to reduce the number of empty cells. Since the hypothesis of this study focused on confusions associated with Stimulus Level, it was logical to maintain Target Consonant, Response, Vowel Context, and Stimulus Level. The data were therefore collapsed across Subjects. As this type of analysis is concerned with model building as opposed to traditional statistical testing, it was felt that collapsing over Subjects provided a means for modeling the effects of primary interest, at the cost of discarding information of secondary interest, specifically, interactions involving Subjects. A review of matrices for individual subjects shows that the most common confusions were essentially the same for all subjects, further supporting the view that inter-subject differences in error pattern were of secondary interest.

#### Error Patterns for Voiced Consonants at I- and I+

The results of the log linear analysis for the voiced consonants are summarized in Table 4.13. In this and subsequent tables, the variables are Target Consonant (T), Response (R), Stimulus Level (L), and Vowel Context (V). Table 4.13 provides a summary of the development of a model that is a best fit to the data in terms of optimizing a chi square goodness of fit criterion. The modeling procedure begins with the simplest model containing only the main effects (R, T, L, V) . As the table shows, for this model, the goodness of fit test based upon the

Table 4.13 Development of Log Linear Models for Voiced Consonants  
(R=Response; T=Target; L=Stimulus Level; V=Vowel Context)

MODEL	EFFECT ADDED	DF	L. R. CHI SQR	PROB.
R,T,L,V		412	1141.62	0.000
RT,L,V *	RT	357	497.97	0.000
DIFFERENCE		55	643.65	0.000
RL,T,V	RL	404	1138.39	0.000
DIFFERENCE		8	3.23	0.919
RV,T,L	RV	396	1076.18	0.000
DIFFERENCE		16	65.44	0.000
R.TL.V	TL	404	1133.91	0.000
DIFFERENCE		8	7.71	0.462
R,TV,L	TV	396	1097.57	0.000
DIFFERENCE		16	44.05	0.002
R,T,LV	LV	410	1137.93	0.000
DIFFERENCE		2	3.69	0.158

likelihood ratio, shows a chi square of 1141.62 for 412 degrees of freedom. This value of chi square is highly significant (less than .0005) and a more complex model is needed to provide an adequate fit to the data. The next level of complexity is introducing a two way interaction to the model. Of the five models involving a single two way interaction, the model RT, L, V shows the greatest reduction in the chi square value. For this model, chi square has a value of 497.97 for 357 degrees of freedom. The probability of obtaining this value of chi square by chance alone is less than .0005. This model provides a barely adequate fit to the data. Introducing the next level of complexity entails adding a second two way interaction. In this instances the best fit model is RV, RT, L. This model has a chi square value of 432.53 for 341 degrees of freedom. The reduction in chi square is only 65.44 compared to the simpler model RT, L, V and has a probability of .0006. The next level of complexity was the introduction of a three way interaction term. In this case, the model with the best fit to the data, RTL,V no longer has a significant chi-square value associated with it ( $p=.1162$ ).

For practical purposes, the model RT, L, V provides a concise, useful summary of the data. The model RT, RV, L provides a slightly better fit, although at the expense of greater complexity.

A log linear analysis was also performed for consonants grouped by manner of articulation and is summarized in Table 4.14. The table shows that the simple model R, T, L, V has a chi square value of 346.58 for 46 degrees of freedom with a highly significant associated probability ( $p < .0005$ ). Adding a two

way interaction again results in the model RT, L, V as the best fit to the data with a chi square of 77.81 for 42 degrees of freedom. This represents a reduction in the chi square value of 268.76 and an associated probability of .0006. Adding additional two way interaction terms to the model results in a best fit model which no longer has a significant probability ( $p=.085$ ).

Since this model represents a reasonable, practical fit to the data, it's parameters can be used to calculate the expected errors and thus to view the predicted error patterns. Table 4.15 shows parameter estimates produced by the model RT, L, V. Several observations can be made from the table. First, the Response of 'nasal' or 'stop' is the largest main effect. The Vowel Context and Stimulus Level effects are smaller. By far, the RT interaction is the dominant term. Furthermore it can be seen that the nasal consonants make the greatest contribution to the RT interaction.

The method of calculating each cell of the predicted matrix is demonstrated in Appendix B.

### Error Patterns for Voiceless Consonants at I- and I+

The results of developing models for best fit of the data are presented in Table 4.16 and are similar to those for the voiced consonant data. The greatest effect on the Chi Square goodness of fit is achieved by adding the term RT to the model R,T,L,V where the Chi Square of 552.45 is reduced to 284.09 ( $p=.003$ ). Again, the model RT, L, V provides the best fit to the data for models with a single two way interaction. The best fit model for the next order of complexity is the model RV, RT, L. This model reduces the chi square value by 57.71 to 226.38. The probability associated with this model is .0613 and is no longer significant.

Table 4.14 Development of Log Linear Models for Voiced Consonants Grouped by Manner of Articulation (R=Response; T=Target L=Level; V=Vowel Context).

MODEL	EFFECT ADDED	DF	L. R. CHI SQR	PROB.
R,T,L,V		46	346.58	0.000
RT,L,V*	RT	42	77.81	0.001
DIFFERENCE		4	268.76	0.000
RL,T,V	RL	44	345.80	0.000
DIFFERENCE		2	0.78	0.677
RV,T,L	RV	42	334.13	0.000
DIFFERENCE		4	12.45	0.014
R.TL.V	TL	44	346.42	0.000
DIFFERENCE		2	0.16	0.924
R,TV,L	TV	42	319.20	0.000
DIFFERENCE		4	27.38	0.000
R,T,LV	LV	44	342.80	0.000
DIFFERENCE		2	3.78	0.151
ADDING TERMS TO RT,L,V YIELDED BEST MODEL OF RTV,L				
RTV,L		26	19.70	0.806

\* = Best Fit

Table 4.15 Parameter Estimates of Model RT, L, V  
for Voiced Consonants Grouped by Manner of Articulation.

Response			Level		
Nasal	Stop	Fric	I-	I+	
-0.314	0.306	0.008	-0.041	0.041	
Target			Vowel Context		
Nasal	Stop	Fric	a	i	u
-0.051	0.034	0.017	-0.105	0.066	0.039
RT Interaction					
Target	Response				
	Nasal	Stop	Fric		
Nasal	0.863	-0.549	-0.314		
Stop	-0.360	0.177	0.183		
Fric	-0.502	0.372	0.130		

Table 4.16 Development of Log Linear Models for Voiceless Consonants (R=Response; T=Target; L=Level; V=Vowel Context).

MODEL	EFFECT ADDED	DF	L. R. CHI SQ	PROB.
R,T,L,V		236	552.45	0.000
RT,L,V*	RT	207	284.09	0.000
DIFFERENCE		29	268.37	0.000
RL,T,V	RL	230	551.10	0.000
DIFFERENCE		6	1.35	0.969
RV,T,L	RV	224	494.74	0.000
DIFFERENCE		12	57.71	0.000
R.TL.V	TL	230	547.55	0.000
DIFFERENCE		6	4.90	0.557
R,TV,L	TV	224	516.64	0.000
DIFFERENCE		12	35.81	0.003
R,T,LV	LV	234	549.72	0.000
DIFFERENCE		2	2.74	0.254
ADDING TERMS TO RT,L,V YIELDS BEST MODEL OF RV,RT,L				
RV,RT,L		195	226.38	0.0613

\* = Best Fit

**Table 4.17 Summary of Log Linear model testing for voiceless  
consonant errors (R=Response; T=Target; L=Level; V=Vowel Context)**

MODEL	EFFECT ADDED	DF	L. R. CHI SQ	PROB.
R,T,L,V		236	552.45	0.000
RT,L,V*	RT	207	284.09	0.000
DIFFERENCE		29	268.37	0.000
RL,T,V	RL	230	551.10	0.000
DIFFERENCE		6	1.35	0.969
RV,T,L	RV	224	494.74	0.000
DIFFERENCE		12	57.71	0.000
R.TL.V	TL	230	547.55	0.000
DIFFERENCE		6	4.90	0.557
R,TV,L	TV	224	516.64	0.000
DIFFERENCE		12	35.81	0.003
R,T,LV	LV	234	549.72	0.000
DIFFERENCE		2	2.74	0.254
<b>ADDING TERMS TO RT,L,V YIELDS BEST MODEL OF RV,RT,L</b>				
RV,RT,L		195	226.38	0.0613

\* = Best Fit

## Summary of Results

1. The global analysis showed that while discrimination scores at I+ and I- were well matched, the voiceless consonants showed a markedly more rapid change on either side of IMAX when compared to the voiced consonants.

2. The analysis of variance of the error rates showed Target Consonant and Vowel Context, but not Stimulus Level to be significant effects in almost every case. While the main effect Stimulus Level was not significant, several important interactions involving Stimulus Level were observed. When grouped by manner of articulation, four of the subjects showed greater error rates at I+ than I-, particularly for nasal consonants in a Vowel Context of /u/. In addition, the data of all ten subjects showed significantly greater between-manner errors than within-manner errors at I- compared to I+ in a Vowel Context of /u/. Also, in the /u/ Vowel Context, the within-manner error rate increases dramatically. This was not observed with the other Vowel Contexts. When voiceless consonants were grouped in terms of their acoustic energy, the weaker consonants showed significantly higher error rates at I+ than at I- for Vowel Context /u/ while the opposite was observed for Vowel Context /a/.

3. Log linear modeling of the error patterns showed that a model comprised of the RT interaction, the Vowel Context effect, and the Stimulus Level

effect (i.e. the RT, L, V model) predicted the observed confusion matrices adequately. When grouped by manner of articulation, the log linear analysis showed that once again, the RT,L,V model provided an adequate fit to the data. An analysis of the terms in the model showed that the largest effect was the RT interaction and that the largest terms in the RT interaction involved the nasal consonants.

## CHAPTER 5

### DISCUSSION

The present study evaluated the number and type of errors made by ten subjects with cochlear type hearing loss. Error matrices were constructed based upon target and response phonemes, three vowel environments (/a,i,u/), and two intensity conditions (I- and I+). The main hypothesis underlying the present study is that the pattern of errors associated with the I- and I+ conditions would differ significantly.

Prior to relating the obtained results to this hypothesis, it is appropriate to comment on issues pertaining to the way the data were obtained and treated.

The first issue is the accuracy of the estimates of the levels IMAX, I+, and I-. The method of obtaining IMAX, while similar to that of other researchers, is at least as accurate as that of Jerger and Jerger (1971) and Dirks, et al (1977), and that of commonly accepted clinical practice. The step size of 5 dB is smaller than the commonly used 10 dB thus suggesting equal or greater precision of measurement. Additionally, the initial global analysis showed that error rates at I+ and I- were not significantly different from each other but both were significantly lower than the rate obtained at IMAX. Although this procedure used

for estimating IMAX may have been subject to errors of estimation, the primary objective of obtaining stimulus levels I- and I+ on either side of IMAX yielding virtually identical discrimination scores was achieved satisfactorily. The requirement that the scores at I- and I+ be significantly below that at IMAX was also achieved.

A second issue, that of test-retest variability between test sessions, showed sufficient consistency to allow pooling of data over test sessions. However, the combining of data from the two sessions was not without risk. The decision to combine the data, necessitated by the log linear modeling, does impact on the analysis of variance in that higher order interactions involving test sessions cannot be evaluated. Since between-session effects was not of great interest, pooling of data over test sessions was considered to be a reasonable tradeoff in order to gain the information provided by the log linear modeling.

The first finding relating to the underlying hypothesis is that the voiced and voiceless consonants differed in their respective performance intensity functions. Specifically, the decrease in error rate in going from I- to IMAX was greater for voiceless consonants than for voiced consonants. In going from IMAX to I+, the voiced consonants show a marginally greater rate of change than the voiceless consonants. This observation has not been previously reported possibly because the traditional method of studying rollover is to use meaningful words where the voicing dichotomy is ignored. Other studies such as those mentioned previously have found voiceless consonants to have higher error rates than voiced

consonants. However, comparison of the two in subjects showing rollover has not been reported to date.

The steeper slope on the I- side of the function is most likely a result of the fact that voiceless consonants are weaker than their voiced cognates. Because the voiceless consonants contain less energy and because of the raised thresholds of the hearing impaired subjects, there are fewer audible for the subject to make a correct judgment. The voiced consonants, due to their greater acoustic strength, are more likely contain audible cues thus show both lower error rates at I- and a slower change going from I- to IMAX.

At I+, the portion of the signal above the threshold of audibility should exceed that at IMAX. The increase in error rate thus cannot be ascribed to an increase in the number of cues falling below threshold. Rather, some other phenomenon must be responsible. Because of the high levels involved, the effect may be due to an upward spread of masking as identified by Martin et al, (1973); Danaher et al, (1973); Pickett and Danaher, (1975); Hannley and Dorman, (1983). If this argument is valid, the acoustically weaker consonants should be more prone to spread of masking effects, and hence should show a greater relative increase in error rates in going from IMAX to I+. This indeed is the case for most of the weaker voiceless consonants, as shown in Figure 4.4. where /θ, t, k, and f/ show steeper functions than do the stronger consonants /s, p/. The results for the voiced consonants were mixed (see Figure 4.5) and showed only partial support for this interpretation. Consistent with the pattern are /d/, /g/, and

/n/. This pattern of individual consonants having different rollover functions has not been noted in previous research. The only published data showing a similar effect is that of Jerger and Hannley (1983), who found that rollover was primarily attributable to increased vowel errors. The current study did not examine vowel errors. It should also be noted that the subjects showing rollover in the Hannley and Jerger study had confirmed retrocochlear lesions. The subjects in the present study did not show evidence of retrocochlear impairments.

The presence of noise at a constant signal to noise ratio confounds this interpretation but does not nullify it. Given that the signal to noise ratio is constant, it could be said that specific cues would always be masked since they might be lost in the noise floor. Any improvement such as that noted at IMAX would then represent some weak unmasked cue becoming more audible with increasing intensity. The precise nature of that cue is unclear. The presence of noise fails to explain the decrease in performance noted at levels greater than IMAX.

The analysis of the error rates for voiceless consonants supports the notion that acoustic strength of the consonants is related to rollover. The significant Stimulus Level by Vowel Context interaction and Acoustic Strength by Stimulus Level by Vowel interactions revealed that error rates for weak consonants in a context of /u/ increase dramatically at I+ while error rates for the same consonants in a context of /a/, and to a lesser extent /i/, decrease. This pattern

is consistent with the above explanation in that the /u/ vowel has substantial low-frequency power which could result in relatively more upward spread of masking than the other vowels. Important consonantal cues are contained in the second formant transitions which are relatively close in frequency to the very powerful first formant in /u/, and hence are particularly susceptible to upward spread of masking in this vowel context.

Additional findings related to the hypothesis were evident for the voiced consonants when grouped by manner of articulation. The voiced consonants showed a level dependent shift in the types of errors made when paired with /u/.

The nasal consonants show increased error rates at I+ in the context of the /u/ vowel. This observation provides further support for the argument that the close proximity of F1 and F2 in /u/ increases the likelihood of an upward spread of masking contributing to misidentification of consonants that depend on the perception of the low frequency formants.

A major finding of the log linear analysis is that the RT interaction is the dominant effect in predicting the confusion matrices. Further evaluation of the RT interaction shows that the major portion of rollover for voiced consonants is attributable to nasal consonants. The consonantal errors under these conditions were found to be primarily nasal-nasal confusions although there was a concomitant increase in errors of all types at I+ for nasal targets. There was also an increase in the tendency to respond with nasal, regardless of the target type.

Because nasal consonant transitions are low in both amplitude and frequency, the increase in nasal for nasal errors may be consistent with an upward spread of masking. In those cases where nasal targets were heard as a stop or fricative, subjects were presumably not hearing a manner cue such as the F3 'murmur' characteristic of nasals. This too could be a case of upward spread of masking interfering with an important consonantal cue. However, the increased tendency to respond with a nasal at I+ is difficult to explain. Hannley and Jerger (1983) found the major portion of rollover in their retrocochlear subjects was attributable to vowel confusions. Since the spectrum of nasals is similar to that of vowels, the generally poor performance in the perception of nasal consonants may suggest that subjects showing rollover have difficulty discriminating vowels and vowel-like signals at levels above IMAX.

Earlier it was stated that the presence of a noise with a constant signal to noise ratio must be considered in explaining the obtained results. While failing to explain the rollover observed, it does have implications for the failure to see a more robust change in error patterns in going from I- to I+. If the noise had the effect of reducing cues required for correct identification, it would likely have that effect regardless of the presentation level, and thus the effect should be similar at both I- and I+. The fact that some small changes in error patterns were noted suggests that some effect other than the presence of a background noise is contributing to the observed results.

Another factor related to the presence of noise is that of audiometric configuration. It would seem that the effect of a constant S/N would be most apparent with steeply sloping losses and less so with flat losses. In the case of the flat configuration, more of the high frequency cues should be above the noise floor due to the spectrum of the noise. In contrast, the steeply sloping configuration should suffer more from the noise since the noise tends to offset any increased availability of high frequency cues due to increased presentation level. There is some indirect support for this in that the subjects with the steepest sloping losses had the highest error rates. However, in contrast, the four subjects showing increased nasal error rates at I+ were the subjects with the steepest sloping losses. Neither the noise spectrum nor the pure tone configuration would explain this finding since the nasal errors in a context of /u/ most likely involve low frequency cues, which presumably are available to this group.

Finally, in viewing the current findings, it should be remembered that spread of masking effects are but one possible cochlear event that can explain the obtained results. It must be emphasized that there are numerous poorly understood nonlinear effects occurring within a damaged cochlea including abnormal loudness growth, poor frequency resolution, and reduced temporal resolution. Any or all of these effects could be contributing to the current finding.

## Audiological implications

The current study has implications that directly affect the fitting of hearing aids, particularly for subjects exhibiting rollover. The weak consonants showing the steeply sloping functions discussed previously, are often the ones that are targeted for improvement by introducing amplification. To the extent that the amount of amplification raises the signal to IMAX, improvement can be expected. However, once the stimulus level is increased above IMAX, amplification can have a deleterious effect. Assuming this effect is related to an upward spread of masking, an amplifier with multi-band compression might prove beneficial. Using the weak consonants as stimuli, the compression in the lower bands, i.e. frequencies corresponding to F1, might be set to reduce the upward spread of masking of the higher bands. Because the acoustically strong consonants such as /p/ and /s/ show shallow rollover functions, they should not be affected negatively by this compression. At the same time, this type of compression could be designed to place more of the weaker consonants with their more pronounced rollover effects, closer in level to IMAX. This should result in a reduction in consonantal errors, particularly for the weaker consonants with their relatively high error rates.

It has been suggested that much of the effect noted in the present study might be explained by a model where I- errors occur because much of the signal lies below the threshold of audibility and I+ errors occur due to an upward spread of masking. Viewing hearing loss in the context of such a model, it would

be reasonable to think that particular pure tone configurations would more prone to showing rollover. First, there would need to be a high frequency loss to account for the I- side of the function. Second there would need to be considerable better hearing in the low and mid range. Data on rollover obtained by Milner (1982) showed that subjects with essentially normal hearing through approximately 750 Hz. but with substantial high frequency loss are more likely to demonstrate upward spread of masking effects contributing to the errors on the I+ side of the curve. While pure tone configuration was not evaluated as a variable in the present study, three of the four subjects showing the greatest amount of rollover, had configurations characterized by sharply sloping losses beginning at 1 kHz. (.750 kHz thresholds were not generally obtained). The role of pure tone configuration needs to be evaluated in future studies of rollover.

From a diagnostic perspective, the current findings offer a means to assist in differentiating rollover associated with retrocochlear pathology from rollover associated with cochlear etiology. Rather than obtaining only a measure of magnitude (the traditional Rollover Index), an analysis of the types of errors made could serve as additional data in determining site of lesion. If the analysis shows evidence of patterns observed in the present study such as the behavior of acoustically weaker vs. acoustically stronger consonants as well as the manner type errors noted, the suggestion is that the observed rollover is cochlear in origin. In contrast, lack of these patterns with a concomitant increase in vowel errors it I+ compared to IMAX may suggest retrocochlear pathology.

### Comparison with previous studies

While differences in the pattern of rollover between voiced and voiceless consonants has not been observed previously, the majority of research using the CUNY Nonsense Syllable Test agrees with the finding that voiced consonants were less prone to error than the voiceless consonants (Dubno, et al (1982); Dubno and Levitt (1981); Dubno and Dirks (1982). In contrast, Wang and Bilger (1973) showed that in their two final consonant syllable sets, voiceless consonants such as /p,s,θ,t,/ were correctly identified more often than their voiced cognates. This contrary finding is most likely due to differences in the preparation and presentation of the stimuli. Wang and Bilger used an apparatus that limited the duration of each syllable (511 msec). This limitation in overall stimulus duration may have adversely affected the perception of final consonants. Furthermore, these researchers controlled the intensity level of the stimuli to make them approximately equal. The CUNY NST does not specifically control these parameters.

The observation of a significant increase in nasal consonant errors at I+ is not consistent with results from previous studies. Comparisons with other published data (e.g., Dubno and Levitt 1981 and Dubno et al 1982) must be made cautiously as these studies did not use sufficiently high stimulus levels to cause rollover. However, even at lower levels (such as those corresponding to I-) the data presented by Dubno et al (1982) showed nasals to have a generally lower error rate than either stops or fricatives. In that study, final fricatives showed the

highest error rate. In additions, nasals paired with /u/, for both initial and final positions combined showed an error rate between that of /a/ and /i/. Data consistent with the findings of this study have been reported by Dubno and Levitt (1981). They found that nasals in a final position and presented in a noise background, yielded a higher error rate than did either stops or fricatives. Error rate for a context of /u/ was much higher than for /a/ and slightly lower than for /i/. In contrast, Wang and Bilger (1973) found nasal consonants in a final position to have a considerably lower error rate than fricatives and somewhat lower than stops. As noted earlier, however, equipment limitations may have affected their results for consonants on the final position.

Of particular interest in comparing the results of this study with other published data are the findings of Hannley and Dorman (1983) relating of spread of masking effects to speech discrimination. In the latter study, /d/ and /g/ were susceptible to F1 masking while /b/ was relatively immune from such masking. The current study found correct identification /d/ and /g/ to decrease 14% and 22% respectively for I+ compared to I-. In contrast, the error rate for /b/ remained the same or improved at I+. Theses results are consistent with those of Hannley and Dorman (1983) and with the interpretation that the reduction in the perception of /d/ and /g/ at higher stimulus levels is due to spread of masking effects.

The model developed using log linear analysis was dominated by the Target Consonant and Response interaction. If the contention that the subjects in

the current study are typical of the population at large is correct, there should be a similarity in the confusions noted in this study with other published results. The continuum of performance for target phonemes indicated that /θ/ and /ð/ were most often incorrectly identified. This finding is consistent with results of previous studies using final consonants (Wang and Bilger, 1973). Hannley and Jerger (1985), while finding that consonants contributed little to rollover, did find these two consonants had the highest error rates. At the other end of the continuum, /s,sh,z,m/ showed low error rates. The finding relative to /z/ is in opposition to the findings of Wang and Bilger (1973) who found /z/ to have a fairly high error rate. Dubno et al (1982), while not presenting individual phoneme data for the final position did report that mean error rates were least for back consonants (/k,g,sh,ng/) and greatest for front consonants (/p,b,f,v,m/) with middle consonants (/t,d,θ,ð,z,n/) somewhere between the extremes. Dubno and Levitt (1981) report a similar finding for normal listeners when the consonant is in the final position. In the present study, the consonants produced in the middle of the mouth, largely due to the high error rates of /θ/ and /ð/, showed the greatest error rate with the front consonants in between. It is interesting to note that the data for the IMAX condition follow the pattern identified by Dubno et al (1982) with front consonants showing the highest error rate and back consonants the lowest. It would seem that the subjects showing rollover perform somewhat differently than did those of Dubno et al (1982). As the stimuli were similar, this difference may reflect an aspect inherent in subjects showing rollover,

or an intensity effect. The Dubno et al (1982) study did not test at the levels as high as the I+ condition.

The present study found Vowel Context /u/ to yield higher error rates for voiced consonants than either /a/ or /i/, particularly at I+. Other than the study of normal hearing individuals by Dubno and Levitt (1981), most of the cited studies find the vowel context /u/ yielded an error rate lower than that for the other two vowels. However, with the exception of Hannley and Jerger (1985), none of the studies used intensities above 70 db HL. A comparison with Hannley and Jerger is questionable as these authors used meaningful PB monosyllables as their stimuli. Differences in methodology and/or test materials could explain the difference between the current results and those of studies such as Wang and Bilger (1973). However, the lack of consistency with studies using the CUNY NST is more difficult to explain. With no reason to think that the subjects in the present study are unique from the general population, one can infer that it is the stimulus levels selected in the present study that produced the observed effect. In several instances, there is a statistical basis for making that inference. The finding relative to higher error rates at I+ in a context of /u/ is in opposition to what one would predict from the work of Dorman et al (1983). These authors reported that the presence of a stapedial reflex resulted in improved identification of synthetic vowels presented at a relatively high intensity. Presumably, there is some attenuation in low frequency energy. This being the case, one would expect that a Vowel Context of /u/ should benefit most from activation of the

reflex at I+. As has been demonstrated, this was not the case in the current study.

In summary, the comparisons with other published data showed that, with a few exceptions, the data obtained in this study are consistent with the results of other researchers. In particular, good consistency was obtained with the few other investigations dealing with upward spread of masking and consonant identification.

#### Applicability to the general population

It is evident from the above that there were small but significant changes in the error patterns between I- and I+ for the subjects in this study. However, the extent to which these results can be generalized to the cochlear impaired population at large must be addressed. The current sample was comprised of males under the age of 60 years with sensorineural hearing. There are no data to suggest that females of the same age would perform differently under the same conditions. The question of age is important as there are data to suggest that subjects past the sixth decade show decreased speech discrimination ability beyond that expected in view of the degree of peripheral hearing loss (Jerger, 1973). Discrimination scores for these older subjects may thus be contaminated by factors other than sensorineural hearing loss. .

Another factor to consider in generalizing the results of the study is the test material used. As the current study used VC nonsense syllables, one cannot be

sure that CV's would yield similar results. Furthermore, the use of semantically correct materials would likely produce different results.

Finally, it must be remembered that a fixed model was assumed for the data analysis for factors and interactions involving subjects. This assumption makes application to the population at large tenuous. The fact that approximately half the subject sample showed a change in error patterns would suggest that one would not expect to see this effect in the population at large.

## CHAPTER SIX

### CONCLUSIONS AND FUTURE RESEARCH

The present study was designed to evaluate the patterns of errors made by a group of cochlear impaired listeners on a vowel-consonant recognition task in which rollover was exhibited. The hypothesis of the study was that the pattern of errors would be different on either side of the point of maximum recognition (i. e., at stimulus levels I- and I+). The rationale for such a hypothesis was based upon studies which showed reduced consonant perception ability attributed to first formant masking effects.

The present study found small changes in the error patterns. Among these were increasing error rates for nasals at I+ in a context of /u/, a greater increase in error rate for weak voiceless consonants at I+ in a context of /u/, and a shift from between to with category errors in a vowel context of /u/. Furthermore, a difference was noted between voiced and voiceless consonants in the slopes of the performance-intensity function on either side of the peak at IMAX. Individual consonants tended to show the difference in the slope of their functions with acoustically weaker consonants generally showing a sharper peak than the acoustically stronger consonants.

A possible interpretation of the experimental findings is that two processes may be responsible for the rollover effect. On the I- side of function, errors were attributed to portions of the signal falling below the subject's threshold of

audibility. On the I+ side, upward spread of masking is suggested as a contributor to the consonantal errors obtained.

The conclusion to be drawn from the present study is that for the present sample, approximately half of the subjects show a change in error patterns which is consistent with an upward spread of masking phenomenon. However, inter-subject differences do exist and it remains to be seen what factors differentiate subjects demonstrating a change in error patterns from those who do not.

An understanding of rollover and its possible causes has important implications for both diagnostic audiology and hearing aid prescription. Methods for amplifying speech signals to fall on or close to IMAX should improve speech intelligibility. The present study has shown that at least for some subjects, inappropriately high gain selection can have a deleterious effect on speech discrimination.

#### Suggestions for further research

It is recommended that direct measures of susceptibility to upward spread of masking be obtained from individual subjects in order to predict error patterns at I- and I+ for different speech sounds. In addition, the role of the reflex could be evaluated by including subjects grouped by presence and lack of reflex threshold. It is also recommended that a detailed psychoacoustic study of subjects showing a change in error pattern be undertaken to evaluate those factors that might be responsible for this manifestation. The effect of audiometric configuration on rollover should also be evaluated. Finally, materials other than

the VC nonsense syllables, and subjects other than middle aged males should be considered in future studies.

## Appendix A

### Pilot Project

## APPENDIX A

## Pilot Project Results

The primary purpose of the pilot project was to determine the relative incidence of rollover in a group of adult males drawn from the projected population.

Subject selection criteria were identical to those presented in this proposal. Methodology was similar with three differences. First, S/N was varied from +10 to 0. This was done to establish a level that would yield a greater number of subjects demonstrating rollover. The second difference concerned the test material. For the pilot project, all subtests were used rather than just VC subtests.

In the early stages of piloting, it was observed that more subjects demonstrated rollover when S/N = 0 dB. This level was maintained for the duration of the pilot project. Of the 28 subjects tested, 14 showed a pattern of rollover although with varying magnitude (range = 7% to 25%). The mean decrease in performance at P+5 was 12.2% with a standard deviation of 6.1%. One subject was tested twice to judge the stability of rollover. This subject maintained the pattern of rollover although the percent change was 4% less on retest.

The errors made by the 14 subjects were organized into error matrices with

voiced and voiceless consonants being treated separately. These matrices suggest several trends which are summarized below

### Voiceless Consonants

The amount of rollover observed for consonants in the initial position was small (6%). Furthermore, both initial /p/ and /k/ were perceived as /t/ more frequently at I+5 than at I-5. These errors alone could account for the magnitude of the rollover. It was also observed that no rollover was obtained when either initial or final consonants are paired with /i/.

### Voiced Consonants

The rollover associated with voiced consonants was found to be more pronounced than that for voiceless consonants (voiced consonant rollover is more than four times greater than that of voiceless consonants). Such a finding is consistent with the prediction of F1 masking F2 cues.

In contrast to the voiceless results, the greatest amount of rollover is seen with consonant final position. It is difficult to explain this finding but a temporal masking phenomenon as suggested by Pickett and Danaher (1975) may have been contributing.

## Appendix B

### Explanation of Log Linear Analysis

## APPENDIX B-Explanation of log linear analysis

Table B.1 shows a partial sample of a typical printout produced by the log linear analysis of the BMDP Statistical Software. In this example, the model  $RT,L,V$  is presented for voiced consonants grouped by place of articulation. In this model, there are four levels of Target Consonant and Response (Labial, Alveolar, Velar, and Other), two levels of Stimulus Level (I- and I+), and three levels of vowel (/a,i,u/). In the example presented below, the expected frequency for one cell is calculated. This cell represents Response=Labial (or  $R_1$ ), Target Consonant=Labial (or  $T_1$ ), Vowel Context= /a/ (or  $V_1$ ), and Stimulus Level=I- (or  $L_1$ ). This is the first cell of the matrix and can be represented by  $RT_{11}, L_1, V_1$ ). The observed frequency for this cell is 31. The expected frequency is calculated from the parameters of the log linear model. These parameters are called *Lambda*<sub>x</sub> (henceforth represented by  $\lambda_x$ ) where  $x$  represents a main effect or interaction specified in the model. The *Lambda*<sub>x</sub> take the form of logarithms. In the current example, calculation of the expected frequency for the cell includes  $\lambda_{R1}, \lambda_{T1}, \lambda_{L1}, \lambda_{V1}$ , and  $\lambda_{RT11}$ . Note that when an interaction is specified (e.g.  $RT_{11}$  in this case), the model includes not only the interaction term (RT) but also the component main effects (i.e. R and T). In addition, a parameter for the overall mean ( $\lambda_\theta$ ) is included in the calculation. Each of the  $\lambda$ 's is presented in Table B.1.

The predicted frequency of error cell 1,1 is given by the formula:

$$y = \text{antilog}(\lambda\theta + \lambda R1 + \lambda T1 + \lambda RT11 + \lambda L1 + \lambda V1)$$

where  $y$  is the expected error frequency in cell (1,1) and the  $\lambda$ 's are the parameters of the model.

Substituting the appropriate values from the table of Lambda values yields:

$$y = \text{antilog}(2.63 + .578 + .398 + (-).359 + (-).041 + (-).105)$$

$$y = \text{antilog}(3.164)$$

$$y \approx 23.7$$

The Model RT,L,V would therefore predict the frequency of the cell in question to be 23.7. The observed frequency was .

Using the above formula, the predicted frequencies for any cell in the matrix can be derived. An additional benefit of this analysis is that the magnitude of the  $\lambda$  values can be used to show the relative contribution of various effects and interactions.

## MODEL

RT,L,V

EXPECTED VALUES USING THE ABOVE MODEL

VOWEL	LEVEL	TARGET	RESPONSE			
			LABIAL	ALVEOLAR	VELAR	OTHER
a	I-	LABIAL	23.7	20.5	17.4	15.5

ESTIMATE OF LOG-LINEAR PARAMETER (LAMBDA) IN THE MODEL ABOVE  
 THETA (MEAN) 2.6929

ESTIMATE OF LOG-LINEAR PARAMETER (LAMBDA) IN THE MODEL ABOVE  
 RESPONSE

LABIAL	ALVEOLAR	VELAR	OTHER
0.578	-0.071	-0.215	-0.292

ESTIMATE OF LOG-LINEAR PARAMETER (LAMBDA) IN THE MODEL ABOVE  
 TARGET

LABIAL	ALVEOLAR	VELAR	OTHER
0.398	-0.103	-0.202	-0.094

ESTIMATE OF LOG-LINEAR PARAMETER (LAMBDA) IN THE MODEL ABOVE  
 VOWEL

a	i	u
-0.105	0.066	0.039

ESTIMATE OF LOG-LINEAR PARAMETER (LAMBDA) IN THE MODEL ABOVE  
 LEVEL

I-	I+
-0.041	0.041

ESTIMATE OF LOG-LINEAR PARAMETER (LAMBDA) IN THE MODEL ABOVE  
 TARGET RESPONSE

TARGET	RESPONSE			
LABIAL	LABIAL	ALVEOLAR	VELAR	OTHER
	-0.359	0.147	0.124	0.087

Figure B.1 Summary of  $\lambda$  Values for Example of Log Linear Analysis

## Appendix C

Individual Subject

Error Matrices

SUBJECT A			RESPONSE									
VOWEL	LEVEL	TARGET	m	n	ng	b	d	g	v	z	th	TOTAL
a	LOW	m	0.00	0.33	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.50
		n	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.33
		ng	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14
		d	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
		g	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.29
		v	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.29
		z	0.00	0.43	0.14	0.00	0.00	0.29	0.00	0.00	0.00	0.86
		th	0.00	0.00	0.00	0.14	0.00	0.29	0.00	0.00	0.00	0.43
				0.02	0.10	0.03	0.05	0.03	0.08	0.03	0.00	0.00
	HIGH	m	0.00	0.00	0.00	0.14	0.14	0.00	0.14	0.00	0.00	0.43
		n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17
		ng	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		b	0.17	0.17	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.67
		d	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.17	0.50
		g	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		v	0.14	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.57
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14
		th	0.00	0.14	0.00	0.29	0.14	0.14	0.00	0.14	0.00	0.86
				0.03	0.07	0.02	0.08	0.03	0.09	0.03	0.02	0.04
i	LOW	m	0.00	0.29	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.57
		n	0.14	0.00	0.07	0.00	0.14	0.01	0.04	0.00	0.01	0.42
		ng	0.00	0.29	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.57
		b	0.00	0.00	0.00	0.00	0.00	0.50	0.17	0.00	0.00	0.67
		d	0.00	0.00	0.00	0.14	0.00	0.00	0.29	0.00	0.00	0.43
		g	0.00	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.50
		v	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00	0.33
		z	0.00	0.14	0.00	0.14	0.14	0.00	0.14	0.00	0.00	0.57
		th	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.00	0.57
				0.02	0.08	0.01	0.07	0.09	0.07	0.15	0.03	0.00
	HIGH	m	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		n	0.17	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.50
		ng	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
		b	0.17	0.00	0.00	0.00	0.17	0.00	0.17	0.00	0.00	0.50
		d	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
		g	0.00	0.14	0.14	0.14	0.29	0.00	0.00	0.00	0.00	0.71
		v	0.00	0.14	0.00	0.14	0.14	0.14	0.00	0.00	0.00	0.57
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.29
		th	0.00	0.00	0.00	0.14	0.00	0.00	0.43	0.00	0.00	0.57
				0.07	0.07	0.03	0.06	0.10	0.02	0.08	0.00	0.02
u	LOW	m	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.14	0.00	0.43
		n	0.29	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.57
		ng	0.33	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.50
		b	0.00	0.00	0.17	0.00	0.00	0.17	0.50	0.00	0.00	0.83
		d	0.00	0.00	0.14	0.14	0.00	0.00	0.29	0.00	0.00	0.57
		g	0.00	0.00	0.00	0.43	0.00	0.00	0.14	0.00	0.00	0.57
		v	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		z	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.29
		th	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.17	0.00	0.67
				0.07	0.00	0.03	0.13	0.03	0.05	0.14	0.03	0.00
	HIGH	m	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.33
		n	0.57	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.86
		ng	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		b	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.33
		d	0.00	0.00	0.00	0.29	0.00	0.00	0.14	0.00	0.00	0.43
		g	0.00	0.29	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.57
		v	0.17	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.33
		z	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
		th	0.00	0.00	0.00	0.29	0.00	0.14	0.14	0.00	0.00	0.57
				0.11	0.05	0.00	0.10	0.00	0.05	0.08	0.03	0.00

SUBJA			RESPONSE								
VOWEL	LEVEL	TARGET	p	t	k	f	th	s	sh	TOTAL	
a	LOW	p	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		t	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.50
		k	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14
		f	0.29	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.57
		th	0.29	0.14	0.14	0.14	0.00	0.00	0.00	0.00	0.71
		s	0.43	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.57
		sh	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.29
				0.17	0.08	0.04	0.02	0.06	0.02	0.02	0.42
	HIGH	p	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.29	0.43
		t	0.86	0.00	0.14	0.00	0.00	0.00	0.00	0.00	1.00
		k	0.00	0.29	0.00	0.00	0.14	0.00	0.00	0.00	0.43
		f	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.14	0.43
		th	0.43	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.57
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33
sh		0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.29	
			0.18	0.08	0.08	0.00	0.04	0.00	0.11	0.50	
i	LOW	p	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.50
		t	0.29	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.57
		k	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		f	0.14	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.57
		th	0.00	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.43
		s	0.14	0.57	0.00	0.00	0.14	0.00	0.00	0.00	0.86
		sh	0.00	0.00	0.00	0.43	0.14	0.00	0.00	0.00	0.57
				0.10	0.25	0.09	0.06	0.04	0.00	0.00	0.54
	HIGH	p	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		t	0.17	0.00	0.33	0.00	0.00	0.00	0.17	0.00	0.67
		k	0.14	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.29
		f	0.14	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.57
		th	0.00	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.57
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14
sh		0.14	0.00	0.14	0.29	0.00	0.00	0.00	0.00	0.57	
			0.09	0.08	0.17	0.04	0.00	0.04	0.02	0.44	
u	LOW	p	0.00	0.29	0.14	0.00	0.00	0.14	0.00	0.00	0.57
		t	0.29	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.57
		k	0.57	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.71
		f	0.29	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.43
		th	0.14	0.14	0.14	0.14	0.00	0.00	0.00	0.00	0.57
		s	0.14	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.43
		sh	0.00	0.17	0.00	0.33	0.00	0.00	0.00	0.00	0.50
				0.20	0.11	0.08	0.11	0.02	0.02	0.00	0.54
	HIGH	p	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.29
		t	0.14	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.57
		k	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.43
		f	0.43	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.57
		th	0.17	0.17	0.17	0.00	0.00	0.00	0.17	0.00	0.67
		s	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.14	0.71
sh		0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.57	
			0.15	0.04	0.09	0.10	0.08	0.04	0.04	0.54	

SUBJECT B		RESPONSE										TOTAL
VOWEL LEVEL TARGET		m	n	ng	b	d	g	v	z	th		
a	LOW	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ng	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		b	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14
		d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		g	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.43
		v	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14
		z	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.29	0.00	0.43
		th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.05	0.00	0.05	0.02	0.03	0.02	0.03
i	HIGH	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		n	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.01
		ng	0.14	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14
		d	0.00	0.00	0.00	0.43	0.00	0.00	0.29	0.00	0.00	0.71
		g	0.00	0.00	0.00	0.33	0.00	0.00	0.17	0.17	0.00	0.67
		v	0.00	0.00	0.00	0.17	0.00	0.00	0.50	0.50	0.00	1.17
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.00	0.43	0.00	0.00	0.14	0.00	0.00	0.57
			0.02	0.03	0.01	0.17	0.00	0.00	0.07	0.11	0.00	0.40
u	LOW	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		n	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
		ng	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
		b	0.00	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.43
		d	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.33
		g	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.50
		v	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.43
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.00	0.29	0.43	0.00	0.14	0.00	0.00	0.86
			0.07	0.03	0.00	0.12	0.10	0.02	0.03	0.02	0.00	0.38
u	HIGH	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		n	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.57
		ng	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
		b	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.67
		d	0.00	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.50
		g	0.00	0.00	0.00	0.29	0.14	0.00	0.00	0.14	0.00	0.57
		v	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.14	0.00	0.57
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	0.57
			0.05	0.08	0.00	0.08	0.08	0.07	0.04	0.05	0.00	0.45

SUBJ B		VOWEL LEVEL TARGET						RESPONSE						
		p	t	k	f	th	s	sh	TOTAL					
a	LOW	p	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.14	0.00	0.00	0.43	
		t	0.00	0.00	0.00	0.00	0.00	0.86	0.00	0.86	0.00	0.00	0.86	
		k	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.33	
		f	0.14	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	
		th	0.14	0.00	0.29	0.29	0.00	0.14	0.00	0.14	0.00	0.00	0.86	
		s	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	
		sh	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	
			0.06	0.00	0.04	0.13	0.00	0.18	0.00	0.41				
		HIGH	p	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
		t	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	
	k	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43		
	f	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14		
	th	0.00	0.50	0.00	0.13	0.00	0.38	0.00	1.00	0.00	0.00	1.00		
	s	0.14	0.00	0.00	0.14	0.00	0.00	0.29	0.57	0.00	0.00	0.57		
	sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.08	0.14	0.10	0.04	0.00	0.05	0.04	0.45					
i	LOW	p	0.00	0.00	0.14	0.29	0.00	0.00	0.00	0.14	0.00	0.00	0.43	
		t	0.29	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.43	
		k	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.29	
		f	0.00	0.00	0.14	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.29	
		th	0.14	0.14	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.00	0.57	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		sh	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	
			0.08	0.02	0.06	0.06	0.04	0.04	0.00	0.31				
		HIGH	p	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	
		t	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.17	
	k	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14		
	f	0.00	0.00	0.30	0.00	0.57	0.00	0.00	0.57	0.00	0.00	0.57		
	th	0.14	0.00	0.00	0.29	0.00	0.00	0.00	0.43	0.00	0.00	0.43		
	s	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.14		
	sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.04	0.04	0.00	0.04	0.13	0.00	0.00	0.25					
u	LOW	p	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.43	
		t	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.43	
		k	0.67	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.83	
		f	0.14	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.43	
		th	0.00	0.00	0.14	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.43	
		s	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.71	
		sh	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.29	
			0.16	0.02	0.02	0.27	0.04	0.00	0.00	0.51				
		HIGH	p	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	
		t	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	
	k	0.63	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	1.00		
	f	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50		
	th	0.14	0.29	0.14	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.57		
	s	0.00	0.00	0.00	0.33	0.00	0.00	0.17	0.50	0.00	0.00	0.50		
	sh	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.43	0.00	0.00	0.43		
		0.20	0.09	0.02	0.10	0.00	0.06	0.02	0.49					

SUBJECT C		RESPONSE										TOTAL
VOWEL LEVEL TARGET		m	n	ng	b	d	g	v	z	th		
a	LOW	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ng	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14
		d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		v	0.00	0.00	0.00	0.50	0.00	0.17	0.00	0.00	0.00	0.67
		z	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.17
		th	0.29	0.14	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.57
			0.03	0.02	0.00	0.07	0.00	0.05	0.02	0.00	0.00	0.19
	HIGH	m	0.00	0.00	0.00	0.00	0.17	0.00	0.33	0.00	0.50	
		n	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.17	
		ng	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.29	
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		d	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.33	
		g	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	
		v	0.00	0.14	0.00	0.00	0.00	0.33	0.00	0.00	0.29	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.00	0.00	0.13	0.13	0.75	0.00	0.00	0.00	1.00
			0.00	0.05	0.00	0.03	0.05	0.17	0.02	0.04	0.00	0.35
i	LOW	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		n	0.29	0.00	0.07	0.29	0.00	0.01	0.04	0.00	0.01	0.70
		ng	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		d	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50	
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		v	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.67	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.67	
			0.03	0.06	0.01	0.24	0.00	0.00	0.00	0.00	0.00	0.35
	HIGH	m	0.00	0.17	0.00	0.33	0.17	0.00	0.00	0.00	0.67	
		n	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.57	
		ng	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.57	
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	
		d	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.00	0.50	
		g	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.86	
		v	0.00	0.00	0.00	0.14	0.29	0.14	0.00	0.00	0.57	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	
		th	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.57	
			0.03	0.05	0.00	0.28	0.05	0.03	0.07	0.00	0.00	0.51
u	LOW	m	0.00	0.33	0.00	0.00	0.00	0.00	0.33	0.00	0.17	0.83
		n	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		ng	0.29	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.57	
		b	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29	
		d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		g	0.14	0.14	0.00	0.00	0.00	0.29	0.00	0.00	0.57	
		v	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.00	0.00	0.50	0.00	0.00	0.17	0.00	0.67	
			0.10	0.05	0.00	0.07	0.00	0.03	0.10	0.02	0.02	0.39
	HIGH	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		n	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	
		ng	0.17	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.67	
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.29	
		d	0.29	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.43	
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.43	
		v	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.14	0.00	0.00	0.14	0.00	0.00	0.29	0.00	0.57	
			0.14	0.00	0.00	0.03	0.00	0.15	0.04	0.00	0.35	

SUBJ C		RESPONSE							TOTAL		
VOWEL LEVEL TARGET		p	t	k	f	th	s	sh			
a	LOW	p	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.29	
		t	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50	
		k	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.57	
		f	0.29	0.14	0.14	0.00	0.00	0.00	0.00	0.57	
		th	0.75	0.13	0.00	0.13	0.00	0.00	0.00	1.00	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			0.15	0.16	0.09	0.02	0.00	0.00	0.00	0.42	
		HIGH	p	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.43
		t	0.17	0.00	0.33	0.00	0.33	0.00	0.00	0.83	
	k	0.00	0.00	0.00	0.29	0.00	0.00	0.29	0.57		
	f	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.57		
	th	0.29	0.14	0.14	0.00	0.00	0.00	0.00	0.57		
	s	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14		
	sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.11	0.12	0.07	0.04	0.05	0.00	0.06	0.45		
i	LOW	p	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14	
		t	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.17	
		k	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		f	0.14	0.00	0.29	0.00	0.00	0.00	0.00	0.43	
		th	0.00	0.29	0.29	0.00	0.00	0.00	0.00	0.57	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			0.04	0.06	0.08	0.00	0.00	0.00	0.00	0.19	
		HIGH	p	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.57
		t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	k	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14		
	f	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.67		
	th	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.57		
	s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		0.07	0.13	0.08	0.00	0.00	0.00	0.00	0.28		
u	LOW	p	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.29	
		t	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.43	
		k	0.25	0.25	0.00	0.50	0.00	0.00	0.00	1.00	
		f	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.33	
		th	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.57	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		sh	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.33	
			0.14	0.08	0.00	0.18	0.02	0.00	0.00	0.42	
		HIGH	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		t	0.33	0.00	0.17	0.17	0.00	0.00	0.00	0.67	
	k	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.57		
	f	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14		
	th	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.57		
	s	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14		
	sh	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.57		
		0.05	0.02	0.02	0.29	0.00	0.00	0.00	0.38		

SUBJECT D		RESPONSE											TOTAL
VOWEL LEVEL TARGET		m	n	ng	b	d	g	v	z	th			
a	LOW	m	0.00	0.00	0.00	0.14	0.00	0.00	0.29	0.00	0.14	0.57	
	n	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.14	0.43	
	ng	0.14	0.14	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.00	0.71	
	b	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.50	
	d	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.33	0.00	0.57	
	g	0.00	0.00	0.29	0.00	0.29	0.00	0.00	0.33	0.00	0.67	0.57	
	v	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.67	0.29	
	z	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.14	0.00	0.00	0.43	
	th	0.00	0.14	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.43	
			0.02	0.05	0.03	0.05	0.05	0.07	0.08	0.11	0.03	0.48	
HIGH	m	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	
	n	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14	0.14	0.29	
	ng	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	
	b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	g	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.67	
	v	0.00	0.00	0.00	0.14	0.43	0.14	0.00	0.00	0.14	0.00	0.86	
	z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	th	0.00	0.14	0.00	0.14	0.29	0.00	0.00	0.43	0.00	0.00	1.00	
		0.02	0.03	0.00	0.05	0.15	0.02	0.00	0.05	0.03	0.03	0.35	
i	LOW	m	0.00	0.17	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.50	
	n	0.13	0.00	0.07	0.00	0.13	0.01	0.04	0.38	0.01	0.76	0.76	
	ng	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.43	0.43	
	b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	d	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.17	0.17	
	g	0.00	0.00	0.00	0.17	0.00	0.00	0.33	0.00	0.67	0.00	0.57	
	v	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.33	
	z	0.00	0.00	0.00	0.13	0.50	0.13	0.13	0.13	0.13	0.00	1.00	
	th	0.00	0.00	0.00	0.00	0.10	0.03	0.06	0.13	0.02	0.02	0.49	
		0.03	0.02	0.04	0.05	0.10	0.03	0.06	0.13	0.02	0.02	0.49	
HIGH	m	0.00	0.14	0.00	0.00	0.29	0.00	0.14	0.14	0.00	0.71		
	n	0.17	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.50		
	ng	0.00	0.17	0.00	0.00	0.00	0.17	0.00	0.33	0.00	0.67		
	b	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50		
	d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	g	0.00	0.00	0.00	0.22	0.67	0.00	0.11	0.00	0.00	1.00		
	v	0.00	0.00	0.00	0.17	0.00	0.00	0.50	0.00	0.00	0.67		
	z	0.00	0.00	0.00	0.00	0.29	0.14	0.14	0.14	0.00	0.00	0.71	
	th	0.00	0.00	0.00	0.00	0.10	0.03	0.06	0.13	0.02	0.02	0.49	
		0.03	0.02	0.04	0.05	0.10	0.03	0.06	0.13	0.02	0.02	0.49	
u	LOW	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	ng	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	
	b	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	
	d	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.29	0.00	0.43		
	g	0.17	0.00	0.17	0.17	0.00	0.00	0.00	0.17	0.00	0.67		
	v	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	z	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00		
	th	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33		
		0.03	0.02	0.02	0.02	0.00	0.00	0.05	0.08	0.08	0.00	0.23	
HIGH	m	0.00	0.17	0.43	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.17	
	n	0.29	0.00	0.43	0.00	0.14	0.00	0.00	0.00	0.14	0.00	1.00	
	ng	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.14	0.00	0.57		
	b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17		
	d	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.14	0.00	0.17	
	g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.29		
	v	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.83		
	z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	th	0.00	0.00	0.00	0.14	0.14	0.00	0.14	0.29	0.00	0.00	0.71	
		0.06	0.02	0.05	0.03	0.11	0.00	0.02	0.17	0.02	0.02	0.48	

SUBJD			RESPONSE								
VOWEL	LEVEL	TARGET	p	t	k	f	th	s	sh	TOTAL	
a	LOW	p	0.00	0.14	0.14	0.00	0.00	0.00	0.14	0.43	
		t	0.29	0.00	0.00	0.00	0.29	0.00	0.00	0.57	
		k	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.29	
		f	0.00	0.00	0.14	0.00	0.43	0.00	0.14	0.71	
		th	0.00	0.17	0.00	0.50	0.00	0.00	0.33	1.00	
		s	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.29	
		sh	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	
				0.04	0.04	0.04	0.11	0.14	0.00	0.11	0.49
	HIGH	p	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	
		t	0.56	0.00	0.22	0.00	0.22	0.00	0.00	1.00	
		k	0.00	0.14	0.00	0.29	0.14	0.00	0.14	0.71	
		f	0.50	0.00	0.17	0.00	0.17	0.00	0.00	0.83	
		th	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.43	
sh		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			0.15	0.02	0.06	0.11	0.08	0.00	0.08	0.49	
i	LOW	p	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.29	
		t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		k	0.00	0.14	0.00	0.00	0.14	0.14	0.00	0.43	
		f	0.29	0.00	0.00	0.00	0.43	0.00	0.00	0.71	
		th	0.11	0.33	0.44	0.11	0.00	0.00	0.00	1.00	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	
		sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
				0.06	0.07	0.08	0.02	0.08	0.02	0.09	0.42
	HIGH	p	0.00	0.29	0.29	0.00	0.00	0.00	0.00	0.57	
		t	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.43	
		k	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		f	0.00	0.00	0.14	0.00	0.14	0.14	0.00	0.43	
		th	0.00	0.43	0.14	0.00	0.00	0.00	0.00	0.57	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	
sh		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			0.00	0.10	0.08	0.00	0.08	0.02	0.04	0.33	
u	LOW	p	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17	
		t	0.00	0.00	0.00	0.14	0.29	0.00	0.00	0.43	
		k	0.14	0.00	0.00	0.43	0.29	0.14	0.00	1.00	
		f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.00	0.00	0.43	0.00	0.00	0.29	0.71	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	
		sh	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.43	
				0.02	0.00	0.02	0.14	0.14	0.02	0.06	0.41
	HIGH	p	0.00	0.29	0.00	0.00	0.29	0.00	0.00	0.57	
		t	0.00	0.00	0.14	0.00	0.43	0.00	0.00	0.57	
		k	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		f	0.29	0.00	0.00	0.00	0.43	0.00	0.00	0.71	
		th	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.33	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.71	
sh		0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14		
			0.04	0.06	0.04	0.02	0.16	0.00	0.10	0.44	

SUBJECT E			RESPONSE										
VOWEL	LEVEL	TARGET	m	n	ng	b	d	g	v	z	th	TOTAL	
a	LOW	m	0.00	0.14	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		n	0.33	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	1.00
		ng	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
		b	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
		d	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.71
		g	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	1.00
		v	0.00	0.00	0.00	0.67	0.00	0.11	0.00	0.00	0.00	0.22	1.00
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.14	0.00	0.00	0.57
			0.11	0.02	0.10	0.13	0.07	0.08	0.00	0.02	0.09	0.62	
	HIGH	m	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.17	0.50	
		n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		ng	0.14	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.29	
		b	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14	
		d	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.29	0.29	1.00	
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	
		v	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.14	0.43
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.00	0.00	0.43	0.29	0.29	0.00	0.00	0.00	0.00	1.00
		0.02	0.00	0.03	0.08	0.03	0.05	0.05	0.07	0.07	0.39		
i	LOW	m	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		n	0.17	0.00	0.07	0.00	0.50	0.01	0.04	0.00	0.01	0.80	
		ng	0.29	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.43	
		b	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	
		d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		g	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.17	
		v	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.57	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			0.05	0.00	0.04	0.02	0.06	0.19	0.00	0.00	0.00	0.36	
	HIGH	m	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
		n	0.29	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.71
		ng	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
		b	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.29
		d	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.14	0.43	
		g	0.00	0.00	0.14	0.29	0.00	0.00	0.00	0.00	0.14	0.57	
		v	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.29	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.00	0.00	0.00	0.14	0.29	0.00	0.00	0.00	0.43	
		0.03	0.00	0.11	0.03	0.03	0.15	0.02	0.00	0.03	0.39		
u	LOW	m	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		n	0.29	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.57
		ng	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
		b	0.00	0.00	0.00	0.00	0.17	0.33	0.17	0.00	0.17	0.83	
		d	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	
		g	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14	
		v	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.43	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		th	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	
			0.09	0.05	0.00	0.03	0.03	0.12	0.02	0.00	0.02	0.36	
	HIGH	m	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
		n	0.86	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	1.00
		ng	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.29
		d	0.00	0.00	0.00	0.00	0.00	0.67	0.17	0.00	0.00	0.83	
		g	0.00	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	0.57	
		v	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.43	0.00	0.71	
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	
		th	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.17	0.00	0.67	
		0.14	0.04	0.02	0.10	0.05	0.09	0.07	0.07	0.00	0.57		

SUBJ		RESPONSE										
VOWEL LEVEL TARGET		p	t	k	f	th	s	sh	TOTAL			
a	LOW	p	0.00	0.14	0.14	0.00	0.14	0.00	0.00	0.00	0.43	
		t	0.25	0.00	0.00	0.33	0.42	0.00	0.00	0.00	1.00	
		k	0.00	0.00	0.00	0.33	0.17	0.00	0.00	0.00	0.50	
		f	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	
		th	0.00	0.17	0.00	0.33	0.00	0.00	0.00	0.00	0.50	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.17	
		sh	0.00	0.00	0.00	0.00	0.17	0.33	0.00	0.00	0.50	
			0.06	0.04	0.02	0.14	0.13	0.05	0.02	0.02	0.47	
		HIGH	p	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.29
		t	0.33	0.00	0.00	0.17	0.67	0.00	0.00	0.00	1.17	
	k	0.14	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.43		
	f	0.14	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.43		
	th	0.00	0.14	0.00	0.29	0.00	0.00	0.00	0.00	0.43		
	s	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.14		
	sh	0.00	0.14	0.00	0.14	0.14	0.14	0.00	0.00	0.57		
		0.09	0.06	0.00	0.15	0.16	0.02	0.02	0.02	0.49		
i	LOW	p	0.00	0.17	0.17	0.00	0.17	0.00	0.00	0.00	0.50	
		t	0.00	0.00	0.25	0.00	0.75	0.00	0.00	0.00	1.00	
		k	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		f	0.17	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.33	
		th	0.00	0.43	0.00	0.29	0.00	0.00	0.00	0.00	0.71	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			0.02	0.09	0.06	0.04	0.15	0.00	0.00	0.00	0.36	
		HIGH	p	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.43
		t	0.17	0.00	0.17	0.00	0.50	0.00	0.00	0.00	0.83	
	k	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	f	0.29	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.57		
	th	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.29		
	s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	sh	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29		
		0.06	0.00	0.09	0.00	0.15	0.04	0.00	0.00	0.34		
u	LOW	p	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14	
		t	0.00	0.00	0.57	0.00	0.14	0.00	0.00	0.00	0.71	
		k	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		f	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.43	
		th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
			0.00	0.00	0.08	0.02	0.08	0.00	0.00	0.00	0.18	
		HIGH	p	0.00	0.14	0.00	0.14	0.29	0.00	0.00	0.00	0.57
		t	0.00	0.00	0.57	0.14	0.00	0.14	0.00	0.00	0.86	
	k	0.14	0.00	0.00	0.29	0.14	0.00	0.00	0.00	0.57		
	f	0.14	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.43		
	th	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43		
	s	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.29		
	sh	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.33		
		0.04	0.02	0.08	0.17	0.13	0.02	0.04	0.04	0.50		

SUBJECT F			RESPONSE										
VOWEL	LEVEL	TARGET	m	n	ng	b	d	g	v	z	th	TOTAL	
a	LOW	m	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		n	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.17	0.00	0.67
		ng	0.17	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.50
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.33	0.00	0.50
		d	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.17	0.50
		g	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		v	0.00	0.14	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.14	0.43
		z	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.00	0.00	0.00	0.50
		th	0.00	0.00	0.11	0.56	0.11	0.11	0.11	0.00	0.00	0.00	1.00
			0.02	0.05	0.04	0.06	0.07	0.10	0.09	0.02	0.07	0.52	
	HIGH	m	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
		n	0.14	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.57
		ng	0.50	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.67
		b	0.00	0.00	0.00	0.00	0.43	0.00	0.14	0.00	0.00	0.00	0.57
		d	0.00	0.00	0.00	0.44	0.00	0.22	0.22	0.00	0.00	0.11	1.00
		g	0.00	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.50
		v	0.17	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.33	1.00
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.17
		th	0.00	0.00	0.00	0.14	0.00	0.14	0.14	0.00	0.00	0.00	0.43
		0.09	0.04	0.02	0.12	0.13	0.06	0.09	0.00	0.05	0.60		
i	LOW	m	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	
		n	0.50	0.00	0.07	0.00	0.00	0.01	0.04	0.00	0.01	0.63	
		ng	0.29	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.57	
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		d	0.00	0.14	0.00	0.43	0.00	0.00	0.29	0.00	0.14	1.00	
		g	0.00	0.00	0.17	0.17	0.00	0.00	0.17	0.00	0.17	0.67	
		v	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.14	0.43	
		z	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.29	
		th	0.00	0.14	0.00	0.14	0.29	0.14	0.00	0.14	0.00	0.86	
			0.09	0.03	0.03	0.11	0.05	0.05	0.09	0.02	0.05	0.51	
	HIGH	m	0.00	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
		n	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
		ng	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
		b	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
		d	0.00	0.00	0.00	0.00	0.00	0.29	0.43	0.00	0.00	0.00	0.71
		g	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
		v	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14	0.29
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29
		th	0.00	0.14	0.00	0.14	0.00	0.14	0.29	0.14	0.00	0.86	
		0.04	0.03	0.06	0.03	0.03	0.07	0.08	0.02	0.05	0.40		
u	LOW	m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		n	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		ng	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
		b	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.29
		d	0.00	0.17	0.00	0.50	0.00	0.17	0.00	0.00	0.00	0.17	1.00
		g	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		v	0.00	0.17	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.17	1.00
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14
		th	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.14	0.00	0.43	
			0.02	0.06	0.02	0.13	0.03	0.02	0.05	0.02	0.05	0.39	
	HIGH	m	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
		n	0.50	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.83
		ng	0.17	0.17	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.67
		b	0.00	0.00	0.00	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.33
		d	0.00	0.00	0.00	0.14	0.00	0.29	0.43	0.14	0.00	0.00	1.00
		g	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.50
		v	0.00	0.00	0.00	0.20	0.20	0.10	0.00	0.30	0.20	0.00	1.00
		z	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
		th	0.00	0.00	0.00	0.29	0.00	0.29	0.14	0.29	0.00	0.00	1.00
		0.07	0.06	0.07	0.07	0.06	0.11	0.08	0.08	0.04	0.65		

SUBJF			RESPONSE								
VOWEL	LEVEL	TARGET	p	t	k	f	th	s	sh	TOTAL	
a	LOW	p	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.43	
		t	0.25	0.00	0.25	0.00	0.50	0.00	0.00	1.00	
		k	0.14	0.00	0.00	0.14	0.00	0.14	0.00	0.43	
		f	0.00	0.00	0.00	0.00	0.14	0.29	0.00	0.43	
		th	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.29	
		s	0.00	0.00	0.17	0.00	0.00	0.00	0.17	0.33	
		sh	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.17	
				0.06	0.00	0.14	0.06	0.09	0.06	0.02	0.44
	HIGH	p	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33	
		t	0.20	0.00	0.40	0.00	0.40	0.00	0.00	1.00	
		k	0.17	0.00	0.00	0.33	0.00	0.00	0.00	0.50	
		f	0.33	0.00	0.00	0.00	0.50	0.00	0.00	0.83	
		th	0.00	0.25	0.25	0.13	0.00	0.38	0.00	1.00	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	
sh		0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17		
			0.10	0.04	0.14	0.07	0.13	0.08	0.05	0.60	
i	LOW	p	0.00	0.00	0.29	0.14	0.00	0.00	0.00	0.43	
		t	0.00	0.00	0.17	0.17	0.50	0.00	0.00	0.83	
		k	0.00	0.29	0.00	0.00	0.14	0.00	0.00	0.43	
		f	0.14	0.00	0.00	0.00	0.29	0.00	0.00	0.43	
		th	0.00	0.14	0.00	0.43	0.00	0.00	0.29	0.86	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	
		sh	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	
				0.02	0.06	0.06	0.11	0.13	0.02	0.08	0.49
	HIGH	p	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14	
		t	0.00	0.00	0.14	0.14	0.43	0.00	0.00	0.71	
		k	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.29	
		f	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.29	
		th	0.00	0.14	0.00	0.29	0.00	0.00	0.00	0.43	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
sh		0.00	0.00	0.00	0.00	0.29	0.14	0.00	0.43		
			0.04	0.06	0.02	0.08	0.10	0.02	0.00	0.33	
u	LOW	p	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14	
		t	0.43	0.00	0.00	0.00	0.29	0.00	0.00	0.71	
		k	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.33	
		f	0.14	0.00	0.00	0.00	0.14	0.14	0.14	0.57	
		th	0.14	0.00	0.14	0.14	0.00	0.00	0.14	0.57	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		sh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
				0.10	0.04	0.02	0.02	0.09	0.02	0.04	0.33
	HIGH	p	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.29	
		t	0.43	0.00	0.00	0.00	0.29	0.00	0.00	0.71	
		k	0.00	0.14	0.00	0.43	0.29	0.00	0.00	0.86	
		f	0.43	0.00	0.00	0.00	0.29	0.00	0.00	0.71	
		th	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.33	
		s	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	
sh		0.00	0.00	0.00	0.14	0.14	0.14	0.00	0.43		
			0.12	0.02	0.02	0.11	0.16	0.02	0.04	0.50	

SUBJECT G			RESPONSE										
VOWEL	LEVEL	TARGET	m	n	ng	b	d	g	v	z	th	TOTAL	
a	LOW	m	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
		n	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		ng	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		b	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
		d	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14
		g	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.29
		v	0.00	0.14	0.00	0.57	0.00	0.14	0.00	0.00	0.00	0.00	0.86
		z	0.33	0.17	0.00	0.17	0.17	0.17	0.17	0.00	0.00	0.00	1.00
		th	0.00	0.00	0.00	0.00	0.14	0.14	0.14	0.00	0.00	0.00	0.43
				0.07	0.03	0.00	0.08	0.07	0.10	0.02	0.00	0.02	0.39
	HIGH	m	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.29
		n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14
		ng	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		b	0.00	0.00	0.00	0.00	0.33	0.00	0.17	0.17	0.00	0.00	0.67
		d	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.29
		g	0.14	0.00	0.14	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.57
		v	0.14	0.00	0.00	0.14	0.14	0.14	0.00	0.14	0.14	0.14	0.86
		z	0.17	0.50	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	1.00
		th	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33	0.00	0.00	0.67
				0.05	0.10	0.02	0.03	0.11	0.05	0.02	0.12	0.03	0.53
i	LOW	m	0.00	0.14	0.00	0.00	0.29	0.00	0.00	0.14	0.00	0.00	0.57
		n	0.00	0.00	0.07	0.00	0.17	0.01	0.04	0.33	0.01	0.00	0.63
		ng	0.14	0.00	0.00	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.57
		b	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29	0.14	0.00	0.71
		d	0.00	0.14	0.00	0.29	0.00	0.00	0.29	0.14	0.00	0.00	0.86
		g	0.00	0.00	0.00	0.17	0.33	0.00	0.00	0.00	0.00	0.17	0.67
		v	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.17	0.50
		z	0.00	0.00	0.00	0.14	0.14	0.00	0.29	0.00	0.00	0.00	0.57
		th	0.00	0.00	0.14	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.57
				0.02	0.03	0.02	0.12	0.17	0.00	0.10	0.12	0.05	0.63
	HIGH	m	0.00	0.00	0.00	0.17	0.00	0.17	0.33	0.00	0.00	0.00	0.67
		n	0.17	0.00	0.00	0.00	0.17	0.00	0.00	0.33	0.00	0.00	0.67
		ng	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.29	0.00	0.00	0.57
		b	0.00	0.00	0.00	0.00	0.43	0.00	0.29	0.00	0.14	0.00	0.86
		d	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.43
		g	0.17	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00	0.17	0.67
		v	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.00	0.29
		z	0.00	0.00	0.00	0.00	0.14	0.00	0.29	0.00	0.00	0.00	0.43
		th	0.00	0.14	0.00	0.00	0.29	0.00	0.00	0.14	0.00	0.00	0.57
				0.07	0.03	0.00	0.05	0.15	0.02	0.10	0.08	0.07	0.57
u	LOW	m	0.00	0.00	0.14	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.43
		n	0.29	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		ng	0.50	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.67
		b	0.00	0.00	0.00	0.00	0.29	0.29	0.14	0.00	0.00	0.00	0.71
		d	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.14	0.00	0.00	0.57
		g	0.00	0.00	0.00	0.29	0.14	0.00	0.00	0.00	0.00	0.14	0.57
		v	0.00	0.00	0.00	0.29	0.14	0.00	0.00	0.00	0.14	0.00	0.57
		z	0.00	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.50
		th	0.17	0.00	0.00	0.00	0.17	0.00	0.33	0.00	0.00	0.00	0.67
				0.11	0.00	0.02	0.13	0.17	0.03	0.07	0.02	0.03	0.57
	HIGH	m	0.00	0.17	0.00	0.17	0.00	0.17	0.50	0.00	0.00	0.00	1.00
		n	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.29
		ng	0.17	0.00	0.00	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.50
		b	0.29	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.57
		d	0.14	0.00	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.57
		g	0.17	0.00	0.00	0.17	0.00	0.00	0.33	0.00	0.00	0.00	0.67
		v	0.14	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		z	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		th	0.00	0.00	0.00	0.14	0.00	0.29	0.14	0.00	0.00	0.00	0.57
				0.10	0.03	0.05	0.08	0.03	0.05	0.14	0.03	0.00	0.53



SUBJH			RESPONSE								
VOWEL	LEVEL	TARGET	p	t	k	f	th	s	sh	TOTAL	
a	LOW	p	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.29	
		t	0.17	0.00	0.00	0.17	0.33	0.00	0.00	0.67	
		k	0.14	0.14	0.00	0.00	0.14	0.00	0.14	0.57	
		f	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.57	
		th	0.00	0.29	0.29	0.00	0.00	0.00	0.00	0.57	
		s	0.00	0.29	0.00	0.14	0.14	0.00	0.00	0.57	
		sh	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	
				0.09	0.14	0.06	0.04	0.11	0.00	0.04	0.48
	HIGH	p	0.00	0.00	0.00	0.14	0.14	0.14	0.00	0.43	
		t	0.50	0.00	0.00	0.00	0.33	0.00	0.00	0.83	
		k	0.14	0.00	0.00	0.14	0.14	0.14	0.00	0.57	
		f	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.29	
		th	0.00	0.43	0.00	0.00	0.00	0.14	0.00	0.57	
		s	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14	
sh		0.14	0.00	0.00	0.00	0.14	0.14	0.00	0.43		
			0.13	0.06	0.02	0.04	0.13	0.08	0.00	0.47	
i	LOW	p	0.00	0.00	0.14	0.00	0.00	0.14	0.29	0.57	
		t	0.29	0.00	0.29	0.00	0.14	0.00	0.14	0.86	
		k	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.33	
		f	0.14	0.00	0.14	0.00	0.00	0.14	0.14	0.57	
		th	0.00	0.14	0.00	0.00	0.00	0.00	0.29	0.43	
		s	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.43	
		sh	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.29	
				0.06	0.04	0.16	0.00	0.04	0.04	0.15	0.50
	HIGH	p	0.00	0.00	0.29	0.14	0.00	0.14	0.00	0.57	
		t	0.29	0.00	0.00	0.14	0.00	0.00	0.00	0.43	
		k	0.00	0.14	0.00	0.14	0.29	0.00	0.00	0.57	
		f	0.29	0.00	0.00	0.00	0.00	0.00	0.29	0.57	
		th	0.14	0.14	0.14	0.00	0.00	0.00	0.14	0.57	
		s	0.00	0.00	0.29	0.00	0.14	0.00	0.14	0.57	
sh		0.00	0.17	0.17	0.00	0.17	0.00	0.00	0.50		
			0.10	0.06	0.13	0.06	0.09	0.02	0.08	0.54	
u	LOW	p	0.00	0.00	0.00	0.14	0.14	0.00	0.14	0.43	
		t	0.00	0.00	0.00	0.14	0.14	0.00	0.14	0.43	
		k	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.29	
		f	0.17	0.00	0.33	0.00	0.17	0.00	0.33	1.00	
		th	0.00	0.14	0.00	0.00	0.00	0.14	0.14	0.43	
		s	0.00	0.00	0.00	0.14	0.00	0.00	0.29	0.43	
		sh	0.14	0.00	0.14	0.00	0.00	0.14	0.00	0.43	
				0.06	0.02	0.07	0.08	0.06	0.04	0.15	0.49
	HIGH	p	0.00	0.00	0.00	0.00	0.29	0.00	0.29	0.57	
		t	0.14	0.00	0.00	0.00	0.14	0.14	0.14	0.57	
		k	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.57	
		f	0.00	0.14	0.00	0.00	0.00	0.14	0.14	0.43	
		th	0.00	0.29	0.00	0.00	0.00	0.00	0.29	0.57	
		s	0.50	0.17	0.17	0.00	0.00	0.00	0.17	1.00	
sh		0.00	0.14	0.14	0.00	0.29	0.00	0.00	0.57		
			0.09	0.11	0.04	0.02	0.12	0.06	0.17	0.61	

SUBJECT I			RESPONSE										
VOWEL	LEVEL	TARGET	m	n	ng	b	d	g	v	z	th	TOTAL	
a	LOW	m	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		n	0.43	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.86
		ng	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
		b	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.57
		d	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50
		g	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.29
		v	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29
		th	0.00	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.43
			0.05	0.00	0.02	0.09	0.08	0.02	0.10	0.00	0.03	0.38	
	HIGH	m	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
		n	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.29
		ng	0.00	0.17	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.33
		b	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
		d	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.43	0.71
		g	0.00	0.00	0.14	0.14	0.29	0.00	0.00	0.00	0.00	0.00	0.57
		v	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14	0.00	0.29
		0.03	0.04	0.02	0.08	0.05	0.02	0.02	0.02	0.05	0.31		
i	LOW	m	0.00	0.33	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.67
		n	0.17	0.00	0.07	0.00	0.00	0.01	0.04	0.00	0.01	0.01	0.30
		ng	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
		b	0.14	0.00	0.00	0.00	0.29	0.00	0.29	0.00	0.00	0.00	0.71
		d	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.14	0.14	0.43
		g	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		v	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29
		th	0.00	0.14	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.43
			0.03	0.05	0.02	0.05	0.05	0.04	0.07	0.00	0.05	0.36	
	HIGH	m	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
		n	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		ng	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		b	0.00	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.43
		d	0.00	0.00	0.00	0.43	0.00	0.14	0.00	0.00	0.00	0.00	0.57
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		v	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.33
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29
		th	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50
		0.02	0.03	0.00	0.07	0.03	0.02	0.09	0.00	0.03	0.29		
u	LOW	m	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		n	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.50
		ng	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		b	0.14	0.00	0.00	0.00	0.29	0.14	0.00	0.00	0.14	0.14	0.71
		d	0.00	0.00	0.00	0.17	0.00	0.33	0.00	0.00	0.00	0.00	0.50
		g	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		v	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.33
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.29	0.86	0.86
		th	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.29
			0.02	0.02	0.05	0.06	0.07	0.05	0.08	0.00	0.05	0.39	
	HIGH	m	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		n	0.00	0.00	0.14	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.57
		ng	0.00	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.29
		b	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.71
		d	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.00	0.43
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		v	0.14	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.29	0.71
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17
		th	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.00	0.00	0.83
		0.02	0.06	0.02	0.06	0.13	0.03	0.04	0.06	0.05	0.46		

SUBJ1			RESPONSE							TOTAL	
VOWEL	LEVEL	TARGET	p	t	k	f	th	s	sh		
a	LOW	p	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		t	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.00	0.43
		k	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.29
		f	0.29	0.00	0.00	0.00	0.29	0.14	0.00	0.00	0.71
		th	0.00	0.43	0.29	0.29	0.00	0.00	0.00	0.00	1.00
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17
		sh	0.00	0.00	0.00	0.29	0.00	0.29	0.00	0.00	0.57
				0.06	0.08	0.08	0.08	0.08	0.06	0.02	0.47
	HIGH	p	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14
		t	0.14	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.43
		k	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		f	0.29	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.57
		th	0.00	0.17	0.00	0.33	0.00	0.00	0.00	0.00	0.50
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14
sh		0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.43	
			0.06	0.04	0.02	0.07	0.10	0.02	0.02	0.34	
i	LOW	p	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.29
		t	0.00	0.00	0.14	0.00	0.29	0.00	0.00	0.00	0.43
		k	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		f	0.43	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.57
		th	0.00	0.14	0.00	0.14	0.00	0.00	0.29	0.57	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	
		sh	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	
				0.06	0.06	0.04	0.02	0.08	0.00	0.06	0.33
	HIGH	p	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.29
		t	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.43
		k	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		f	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.17
		th	0.00	0.29	0.00	0.29	0.00	0.00	0.43	1.00	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
sh		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			0.04	0.06	0.02	0.06	0.09	0.00	0.06	0.33	
u	LOW	p	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
		t	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.29
		k	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		f	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14
		th	0.00	0.43	0.14	0.29	0.00	0.00	0.00	0.86	
		s	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	
		sh	0.00	0.00	0.00	0.00	0.33	0.17	0.00	0.50	
				0.04	0.06	0.04	0.04	0.11	0.02	0.00	0.32
	HIGH	p	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.67
		t	0.00	0.00	0.57	0.00	0.29	0.00	0.00	0.00	0.86
		k	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		f	0.14	0.00	0.00	0.00	0.14	0.14	0.00	0.43	
		th	0.00	0.29	0.00	0.29	0.00	0.00	0.00	0.57	
		s	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	
sh		0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29		
			0.04	0.09	0.13	0.04	0.10	0.02	0.04	0.46	

SUBJECT J			RESPONSE										
VOWEL	LEVEL	TARGET	m	n	ng	b	d	g	v	z	th	TOTAL	
a	LOW	m	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
		n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ng	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		b	0.00	0.00	0.17	0.00	0.00	0.17	0.33	0.00	0.00	0.00	0.67
		d	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		v	0.00	0.00	0.13	0.00	0.00	0.00	0.88	0.00	0.00	0.00	1.00
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.17	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.67
			0.00	0.02	0.11	0.00	0.02	0.19	0.00	0.00	0.00	0.33	
	HIGH	m	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.50
		n	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
		ng	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17
		b	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.14	0.00	0.43
		d	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.29
		g	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
		v	0.14	0.00	0.00	0.00	0.14	0.29	0.00	0.00	0.00	0.00	0.57
		z	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		th	0.00	0.00	0.00	0.00	0.14	0.71	0.00	0.00	0.00	0.00	0.86
		0.02	0.04	0.03	0.00	0.06	0.14	0.00	0.07	0.00	0.36		
i	LOW	m	0.00	0.29	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
		n	0.00	0.00	0.07	0.00	0.33	0.01	0.04	0.00	0.01	0.00	0.46
		ng	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		b	0.00	0.00	0.14	0.00	0.57	0.29	0.00	0.00	0.00	0.00	1.00
		d	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.14	0.43
		g	0.00	0.17	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.67
		v	0.14	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.57
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.67
			0.02	0.05	0.07	0.00	0.19	0.10	0.00	0.00	0.04	0.47	
	HIGH	m	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		n	0.17	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
		ng	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14
		b	0.14	0.00	0.00	0.00	0.29	0.14	0.00	0.00	0.00	0.00	0.57
		d	0.00	0.00	0.00	0.14	0.00	0.43	0.14	0.00	0.00	0.00	0.71
		g	0.00	0.17	0.17	0.00	0.33	0.00	0.17	0.00	0.00	0.17	1.00
		v	0.17	0.00	0.00	0.17	0.00	0.33	0.00	0.00	0.00	0.00	0.67
		z	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
		th	0.00	0.00	0.00	0.14	0.43	0.00	0.00	0.00	0.00	0.00	0.57
		0.05	0.03	0.07	0.05	0.13	0.10	0.05	0.00	0.02	0.51		
u	LOW	m	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	0.29
		n	0.50	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
		ng	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.29
		b	0.00	0.00	0.00	0.00	0.14	0.43	0.00	0.14	0.00	0.00	0.71
		d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		g	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.17
		v	0.00	0.14	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.14	0.57
		z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		th	0.00	0.00	0.00	0.14	0.29	0.14	0.00	0.00	0.00	0.00	0.57
			0.07	0.02	0.02	0.05	0.08	0.10	0.00	0.02	0.02	0.36	
	HIGH	m	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.14	0.14	0.14	0.43
		n	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.86
		ng	0.14	0.00	0.00	0.00	0.00	0.29	0.00	0.14	0.00	0.00	0.57
		b	0.43	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.57
		d	0.00	0.00	0.00	0.00	0.00	0.33	0.17	0.17	0.00	0.00	0.67
		g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		v	0.00	0.17	0.00	0.00	0.00	0.33	0.00	0.17	0.00	0.00	0.67
		z	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
		th	0.00	0.00	0.00	0.33	0.00	0.17	0.17	0.00	0.00	0.00	0.67
		0.16	0.02	0.02	0.04	0.00	0.14	0.04	0.08	0.02	0.51		



## Appendix D

Individual Subject

Audiometric Data

<b>Department of Veterans Affairs</b>		AUDIOLOGICAL EVALUATION																	
REASON FOR REFERRAL: <b>Noise Induced</b>										NAME OF REFERRING STATION:									
EXAMINER'S INITIALS	AIR CONDUCTION																		
	RIGHT								LEFT										
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000	
	0	20	30		35	55	60		70	0	20	25	40	40	55	65		65	
MASKING LEVEL																			
EXAMINER'S INITIALS	BONE CONDUCTION																		
	RIGHT								LEFT										
	250	500	1000	1500	2000	3000	4000	250	500	1000	1500	2000	3000	4000					
	10	15	30		30	55	55	10	15	30	40	40	55	65					
MASKING LEVEL																			
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE												PURETONE AVERAGE						
													EAR		FOUR FREQ.				
PROBE RIGHT	RESTING PRESSURE		PVT		STATIC MEASUREMENT		PROBE LEFT	RESTING PRESSURE		PVT		STATIC MEASUREMENT		RIGHT		LEFT			
	-40				1.3			-50				1.2							
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		INTER-TEST CONSISTENCY					
	500	1000	2000	4000	500	1000		500	1000	2000	4000	500	1000	RIGHT		LEFT			
	75	75	85	100	NEG	NEG	75	80	80	95	NEG	NEG							
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		STIMULUS LEFT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE							
REMARKS:																			
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																		
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION								
	1	2	1	2	3	4	5	PBMAX	P1/PB	1	2	3	4	5	PBMAX	P1/PB			
RIGHT EAR																			
LEFT EAR																			
MASKING LEVEL			HL MASKING	/	/	/	/	/	/	HL MASKING	/	/	/	/	/	/			
COMMENTS:																			
LAST NAME - FIRST NAME - MIDDLE INITIAL										AGE		CLAIM NO				SOCIAL SECURITY NO			
Subject A																			
NAME OF EXAMINING STATION OR CLINIC							SIGNATURE OF EXAMINING AUDIOLOGIST							DATE OF EXAM					

Department of Veterans Affairs		AUDIOLOGICAL EVALUATION																
REASON FOR REFERRAL Unknown										NAME OF REFERRING STATION								
EXAMINER'S INITIALS	AIR CONDUCTION																	
	RIGHT								LEFT									
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000
	5	25	35	40	55	70	80		90	15	15	30		45	70	80		80
MASKING LEVEL																		
EXAMINER'S INITIALS	BONE CONDUCTION																	
	RIGHT								LEFT									
	250	500	1000	1500	2000	3000	4000			250	500	1000	1500	2000	3000	4000		
	10	25	30	40	55	70	NR			10	15	30		40	70	NR		
MASKING LEVEL		55																
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE												PURETONE AVERAGE					
	PROBE RIGHT	RESTING PRESSURE	PVT	STATIC MEASUREMENT		PROBE LEFT	RESTING PRESSURE	PVT	STATIC MEASUREMENT		EAR	FOUR FREQ.						
	-10		1.8			0		1.8		RIGHT								
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		LEFT				
	500	1000	2000	4000	500	1000		500	1000	2000	4000	500	1000	RIGHT				
	85	85	95	110	NEG	NEG	75	80	85	110	NEG	NEG	LEFT					
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		STIMULUS LEFT	PSI LATERAL AR THRESHOLDS				HALF-LIFE		INTER-TEST CONSISTENCY				
														RIGHT	LEFT			
REMARKS																		
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																	
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION							
	1	2		1	2	3	4	5	PBMAX	PI/PB		1	2	3	4	5	PBMAX	PI/PB
RIGHT EAR			%								%							
LEFT EAR																		
MASKING LEVEL			HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL
COMMENTS																		
LAST NAME, FIRST NAME, MIDDLE INITIAL Subject B										AGE		CLAIM NO				SOCIAL SECURITY NO		
NAME OF EXAMINING STATION OR CLINIC						SIGNATURE OF EXAMINING AUDIOLOGIST						DATE OF EXAM						

<b>Department of Veterans Affairs</b>										<b>AUDIOLOGICAL EVALUATION</b>																
REASON FOR REFERRAL: <b>Noise Induced</b>										NAME OF REFERRING STATION:																
EXAMINER'S INITIALS	AIR CONDUCTION																									
	RIGHT									LEFT																
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000								
	20	20	30	45	60		75		85	20	20	30	45	60		75		85								
MASKING LEVEL																										
EXAMINER'S INITIALS	BONE CONDUCTION																									
	RIGHT									LEFT																
	250	500	1000	1500	2000	3000	4000			250	500	1000	1500	2000	3000	4000										
	15	15	30	40	60		70		15	15	30	40	60		70											
MASKING LEVEL																										
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE														PURETONE AVERAGE											
	PROBE RIGHT	RESTING PRESSURE			PVT			STATIC MEASUREMENT			PROBE LEFT	RESTING PRESSURE			PVT			STATIC MEASUREMENT			EAR	FOUR FREQ.				
		0						1.1				0						1.5					RIGHT	LEFT		
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS						REFLEX DECAY						STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS						REFLEX DECAY						INTER-TEST CONSISTENCY
	500	1000	2000	4000	500	1000	NEG	NEG	500	1000	2000	4000		500	1000	75	80	100	105	NEG	NEG	RIGHT	LEFT			
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS						HALF-LIFE						STIMULUS LEFT	IPSI LATERAL AR THRESHOLDS						HALF-LIFE						
REMARKS:																										
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																									
	SRT		RIGHT EAR RECOGNITION										LEFT EAR RECOGNITION													
	1	2	1	2	3	4	5	PBMAX	PI/PB	1	2	3	4	5	PBMAX	PI/PB										
	RIGHT EAR		%										%													
	LEFT EAR		HL										HL													
MASKING LEVEL																										
COMMENTS:																										
LAST NAME - FIRST NAME - MIDDLE INITIAL										AGE		CLAIM NO				SOCIAL SECURITY NO										
Subject C																										
NAME OF EXAMINING STATION OR CLINIC										SIGNATURE OF EXAMINING AUDIOLOGIST										DATE OF EXAM						

Department of Veterans Affairs		AUDIOLOGICAL EVALUATION																	
REASON FOR REFERRAL Unknown										NAME OF REFERRING STATION									
EXAMINER'S INITIALS	AIR CONDUCTION																		
	RIGHT									LEFT									
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000	
	10	35	45		60		70	80	90	10	25	35	55	60		70	80	90	
MASKING LEVEL																			
EXAMINER'S INITIALS	BONE CONDUCTION																		
	RIGHT									LEFT									
	250	500	1000	1500	2000	3000	4000			250	500	1000	1500	2000	3000	4000			
	10	30	45		55		70			10	30	30	55	55		70			
MASKING LEVEL		75																	
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE														PURETONE AVERAGE				
	PROBE RIGHT	RESTING PRESSURE	PVT	STATIC MEASUREMENT		PROBE LEFT	RESTING PRESSURE	PVT	STATIC MEASUREMENT		EAR	FOUR FREQ.							
	0		1.1			-25		1.3		RIGHT									
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		LEFT					
	500	1000	2000	4000	500	1000		500	1000	2000	4000	500	1000	RIGHT					
	80	85	95	105	NEG	NEG	90	90	95	100	NEG	NEG	LEFT						
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		STIMULUS LEFT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		INTER-TEST CONSISTENCY					
														RIGHT	LEFT				
REMARKS:																			
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																		
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION								
	1	2	1	2	3	4	5	PBMAX	PI/PB	1	2	3	4	5	PBMAX	PI/PB			
	RIGHT EAR																		
	LEFT EAR																		
MASKING LEVEL		HL MASKING								HL MASKING									
COMMENTS:																			
LAST NAME - FIRST NAME - MIDDLE INITIAL Subject D										AGE		CLAIM NO				SOCIAL SECURITY NO			
NAME OF EXAMINING STATION OR CLINIC						SIGNATURE OF EXAMINING AUDIOLOGIST						DATE OF EXAM							

<b>Department of Veterans Affairs</b>		<b>AUDIOLOGICAL EVALUATION</b>																	
REASON FOR REFERRAL <b>Noise Induced</b>										NAME OF REFERRING STATION									
EXAMINER'S INITIALS	AIR CONDUCTION																		
	RIGHT									LEFT									
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000	
	15	20	30		35		50	55	70	5	20	30		35		50	65	80	
MASKING LEVEL																			
EXAMINER'S INITIALS	BONE CONDUCTION																		
	RIGHT									LEFT									
	250	500	1000	1500	2000	3000	4000			250	500	1000	1500	2000	3000	4000			
	15	20	25		30		50		5	20	25		30		50				
MASKING LEVEL		35																	
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE														PURETONE AVERAGE				
	PROBE RIGHT	RESTING PRESSURE		PVT		STATIC MEASUREMENT		PROBE LEFT	RESTING PRESSURE		PVT		STATIC MEASUREMENT		EAR	FOUR FREQ.			
		-50				1.8			0				1.6		RIGHT				
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		LEFT	INTER-TEST CONSISTENCY				
	500	1000	2000	4000	500	1000		500	1000	2000	4000	500	1000	NEG				NEG	
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		STIMULUS LEFT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		RIGHT	LEFT				
REMARKS																			
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																		
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION								
	1	2	1	2	3	4	5	PBMAX	PI/PB	1	2	3	4	5	PBMAX	PI/PB			
RIGHT EAR																			
LEFT EAR																			
MASKING LEVEL		HL	/	/	/	/	/	/	/	HL	/	/	/	/	/	/			
COMMENTS:																			
LAST NAME - FIRST NAME - MIDDLE INITIAL <b>Subject E</b>										AGE		CLAIM NO.				SOCIAL SECURITY NO.			
NAME OF EXAMINING STATION OR CLINIC						SIGNATURE OF EXAMINING AUDIOLOGIST						DATE OF EXAM							

<b>Department of Veterans Affairs</b>										<b>AUDIOLOGICAL EVALUATION</b>											
REASON FOR REFERRAL <b>Noise Induced</b>										NAME OF REFERRING STATION											
EXAMINER'S INITIALS	AIR CONDUCTION																				
	RIGHT									LEFT											
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000			
	10	20	40		45		50		65	10	20	40		45		50		65			
MASKING LEVEL																					
EXAMINER'S INITIALS	BONE CONDUCTION																				
	RIGHT									LEFT											
	250	500	1000	1500	2000	3000	4000			250	500	1000	1500	2000	3000	4000					
	5	20	35		45		50			5	20	35		45		50					
MASKING LEVEL																					
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE																PURETONE AVERAGE				
	PROBE RIGHT	RESTING PRESSURE	PVT			STATIC MEASUREMENT		PROBE LEFT	RESTING PRESSURE	PVT			STATIC MEASUREMENT		EAR	FOUR FREQ.					
0					1.4		0					1.3		RIGHT							
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		LEFT	INTER-TEST CONSISTENCY						
	500	1000	2000	4000	500	1000		500	1000	2000	4000	500	1000				RIGHT	LEFT			
	80	80	95	95	NEG	NEG		80	85	95	95	NEG	NEG								
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		STIMULUS LEFT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE									
REMARKS																					
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																				
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION										
	1	2		1	2	3	4	5	PBMAX	P1/PB		1	2	3	4	5	PBMAX	P1/PB			
	RIGHT EAR		%									LEFT EAR		%							
	LEFT EAR		HL									LEFT EAR		HL							
MASKING LEVEL		/									MASKING LEVEL		/								
COMMENTS:																					
LAST NAME - FIRST NAME - MIDDLE INITIAL <b>Subject F</b>										AGE		CLAIM NO				SOCIAL SECURITY NO					
NAME OF EXAMINING STATION OR CLINIC							SIGNATURE OF EXAMINING AUDIOLOGIST							DATE OF EXAM							

<b>Department of Veterans Affairs</b>		<b>AUDIOLOGICAL EVALUATION</b>																
REASON FOR REFERRAL <b>Sudden Onset-Idiopathic</b>										NAME OF REFERRING STATION								
EXAMINER'S INITIALS	AIR CONDUCTION																	
	RIGHT									LEFT								
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000
	60	65	60		70	70	80		65	60	65	60		55		60		65
MASKING LEVEL																		
EXAMINER'S INITIALS	BONE CONDUCTION																	
	RIGHT									LEFT								
	250	500	1000	1500	2000	3000	4000			250	500	1000	1500	2000	3000	4000		
	55	65	65		65		NR		55	65	65		55		60			
MASKING LEVEL																		
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE														PURETONE AVERAGE			
	PROBE RIGHT	RESTING PRESSURE	PVT	STATIC MEASUREMENT			PROBE LEFT	RESTING PRESSURE	PVT	STATIC MEASUREMENT			EAR	FOUR FREQ.				
	0		1.3				0		1.2			RIGHT						
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		LEFT	INTER-TEST CONSISTENCY			
	500	1000	2000	4000	500	1000		500	1000	2000	4000	500	1000					
	95	100	100	100	NEG	NEG	100	100	105	110	NEG	NEG						
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		STIMULUS LEFT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		RIGHT	LEFT			
REMARKS:																		
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																	
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION							
	1	2	1	2	3	4	5	PBMAX	PI/PB	1	2	3	4	5	PBMAX	PI/PB		
	RIGHT EAR			%						%								
	LEFT EAR			HL	/	/	/	/	/	HL	/	/	/	/	/	/		
MASKING LEVEL																		
COMMENTS:																		
LAST NAME - FIRST NAME - MIDDLE INITIAL <b>Subject G</b>										AGE		CLAIM NO				SOCIAL SECURITY NO		
NAME OF EXAMINING STATION OR CLINIC						SIGNATURE OF EXAMINING AUDIOLOGIST						DATE OF EXAM						

<b>Department of Veterans Affairs</b>										<b>AUDIOLOGICAL EVALUATION</b>										
REASON FOR REFERRAL <p style="text-align: center; font-size: 1.2em;">Noise Induced</p>										NAME OF REFERRING STATION										
EXAMINER'S INITIALS	AIR CONDUCTION																			
	RIGHT									LEFT										
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000		
	25	25	30		40	40	60	70	35	15	15	30		35	55	60	70	35		
MASKING LEVEL																				
EXAMINER'S INITIALS	BONE CONDUCTION																			
	RIGHT									LEFT										
	250	500	1000	1500	2000	3000	4000			250	500	1000	1500	2000	3000	4000				
	25	25	30		35	40	60			10	10	30		35	55	60				
MASKING LEVEL	45	55													70					
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE														PURETONE AVERAGE					
	RESTING PRESSURE		PVT		STATIC MEASUREMENT		PROBE LEFT		RESTING PRESSURE		PVT		STATIC MEASUREMENT		EAR		FOUR FREQ			
PROBE RIGHT	-70				1.2		PROBE LEFT		-60				1.2		RIGHT		LEFT			
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		STIMULUS RIGHT				CONTRALATERAL AR THRESHOLDS				REFLEX DECAY		INTER-TEST CONSISTENCY			
	500	1000	2000	4000	500	1000	500	1000	2000	4000	500	1000	500	1000	500	1000	RIGHT		LEFT	
	90	90	95	100	NEG	NEG	95	90	95	95	NEG	NEG					RIGHT		LEFT	
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE		STIMULUS LEFT				IPSI LATERAL AR THRESHOLDS				HALF LIFE		INTER-TEST CONSISTENCY			
																	RIGHT		LEFT	
REMARKS:																				
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																			
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION									
	1	2		1	2	3	4	5	PBMAX	P1/PB		1	2	3	4	5	PBMAX	P1/PB		
RIGHT EAR			%																	
LEFT EAR			%																	
MASKING LEVEL			HL MASKING	/	/	/	/	/				HL MASKING	/	/	/	/				
COMMENTS:																				
LAST NAME · FIRST NAME · MIDDLE INITIAL										AGE		CLAIM NO				SOCIAL SECURITY NO				
Subject H																				
NAME OF EXAMINING STATION OR CLINIC						SIGNATURE OF EXAMINING AUDIOLOGIST						DATE OF EXAM								

<b>Department of Veterans Affairs</b>		<b>AUDIOLOGICAL EVALUATION</b>																											
REASON FOR REFERRAL <b>Sudden Onset-Idiopathic</b>										NAME OF REFERRING STATION																			
EXAMINER'S INITIALS	AIR CONDUCTION																												
	RIGHT								LEFT																				
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000											
	55	55	50		45		45		60	55	55	50		45		45		60											
MASKING LEVEL																													
EXAMINER'S INITIALS	BONE CONDUCTION																												
	RIGHT								LEFT																				
	250	500	1000	1500	2000	3000	4000	250	500	1000	1500	2000	3000	4000															
	50	50	50		50		50	50	50	50		50		50															
MASKING LEVEL																													
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE												PURETONE AVERAGE																
	RESTING PRESSURE				PVT		STATIC MEASUREMENT		PROBE LEFT				RESTING PRESSURE		PVT		STATIC MEASUREMENT		EAR	FOUR FREQ									
PROBE RIGHT	0						1.0		PROBE LEFT				0				1.2		RIGHT										
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY				STIMULUS RIGHT				CONTRALATERAL AR THRESHOLDS				REFLEX DECAY				LEFT								
	500	1000	2000	4000	500	1000	500	1000	500	1000	2000	4000	500	1000	500	1000	95	95	90	90	NEG	NEG	95	95	100	95	NEG	NEG	INTER-TEST CONSISTENCY
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF-LIFE				STIMULUS LEFT				IPSI LATERAL AR THRESHOLDS				HALF LIFE				RIGHT	LEFT							
REMARKS																													
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																												
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION																		
	1	2	1	2	3	4	5	PBMAX	PI/PB	1	2	3	4	5	PBMAX	PI/PB													
RIGHT EAR			%							%																			
LEFT EAR																													
MASKING LEVEL			HL MASKING							HL MASKING																			
COMMENTS:																													
LAST NAME - FIRST NAME - MIDDLE INITIAL <b>Subject I</b>								AGE	CLAIM NO	SOCIAL SECURITY NO																			
NAME OF EXAMINING STATION OR CLINIC						SIGNATURE OF EXAMINING AUDIOLOGIST						DATE OF EXAM																	

<b>Department of Veterans Affairs</b>		<b>AUDIOLOGICAL EVALUATION</b>																	
REASON FOR REFERRAL <b>Noise Induced</b>										NAME OF REFERRING STATION									
EXAMINER'S INITIALS	AIR CONDUCTION																		
	RIGHT								LEFT										
	250	500	1000	1500	2000	3000	4000	6000	8000	250	500	1000	1500	2000	3000	4000	6000	8000	
	5	15	15	35	40	45	60	45	35	5	15	25		40	40	75	45	35	
MASKING LEVEL																			
EXAMINER'S INITIALS	BONE CONDUCTION																		
	RIGHT								LEFT										
	250	500	1000	1500	2000	3000	4000		250	500	1000	1500	2000	3000	4000				
	5	10	15	35	40	40	60	5	15	25		40	45	NR					
MASKING LEVEL																			
EXAMINER'S INITIALS	ACOUSTIC IMMITTANCE														PURETONE AVERAGE				
	RESTING PRESSURE		PVT		STATIC MEASUREMENT		PROBE LEFT		RESTING PRESSURE		PVT		STATIC MEASUREMENT		EAR		FOUR FREQ.		
	-40				1.0				-50				1.0		RIGHT				
STIMULUS LEFT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY				STIMULUS RIGHT	CONTRALATERAL AR THRESHOLDS				REFLEX DECAY				INTER-TEST CONSISTENCY	
	500	1000	2000	4000	500	1000	500	1000		500	1000	2000	4000	500	1000	NEG	NEG	RIGHT	LEFT
	70	75	85	105	NEG	NEG			75	80	85	100	NEG	NEG					
STIMULUS RIGHT	IPSI LATERAL AR THRESHOLDS				HALF LIFE				STIMULUS LEFT	IPSI LATERAL AR THRESHOLDS				HALF LIFE				INTER-TEST CONSISTENCY	
																		RIGHT	LEFT
REMARKS:																			
EXAMINER'S INITIALS	SPEECH AUDIOMETRY																		
	SRT		RIGHT EAR RECOGNITION								LEFT EAR RECOGNITION								
	1	2	1	2	3	4	5	PBMAX	PI/PB	1	2	3	4	5	PBMAX	PI/PB			
	RIGHT EAR																		
	LEFT EAR																		
MASKING LEVEL																			
COMMENTS:																			
LAST NAME - FIRST NAME - MIDDLE INITIAL <b>Subject J</b>										AGE		CLAIM NO				SOCIAL SECURITY NO.			
NAME OF EXAMINING STATION OR CLINIC						SIGNATURE OF EXAMINING AUDIOLOGIST						DATE OF EXAM							

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