pure tone sensitivity for speech performance in noise was affected by the frequency response used for speech presentation. For a flat response, tone thresholds and subharmonic PTCs measured at 2 kHz were each similarly effective in predicting speech performance. For a rising response, adequate predictions for speech performance required both tone thresholds and PTCs. The speech measure was a speech identification test from which an overall score was obtained for correct consonant recognition. Of the automatic and psychoacoustic variables measured by Lutman and Clark (1980), threshold sensitivity at 2 kHz was the best predictor of, although only moderately related to, speech performance in noise of 23 hearing-impaired subjects ranging in age from 44 to 72. Subject age also showed some predictive value for speech performance. While frequency resolution and gap detection at 2 kHz were moderately related to speech performance via simple correlations, they lacked uniqueness as predictors of speech performance via multiple regression. The index of speech performance was the signal-to-noise ratio, determined adaptively, that yielded about 70% correct word identification. Using a similar speech performance index, Schacht and Schnolz (1985) measured recognition of consonant words in noise and correlated the S/N ratio for 75 correct with impaired subjects' frequency selectivity, as indicated from psychoacoustic tuning curves. (These curves plot the level at which a function of frequency, of tone, of 4000 Hz in this study. Frequency selectivity values derived from the curves were found to predict the speech recognition level with correlation coefficients in the order of 60. In the broad-band noise and -70 in the low-pass noise among various listeners. Frequency sensitivity accounted for 68% and 54% of the variance. Lonsire et al. (1985) tested 32 severely/ profoundly hearing-impaired adolescents for auditory and psychoacoustic performances, which were analyzed relative to the speech reception thresholds and corresponding global score in quiet. (SRT is the lowest speech level for which the listener identifies 50% correct.) Between the two measures, the SRT showed somewhat better relations to the auditory measures and the word discrimination scores. Of course, the SRT showed the highest relations to pure tone threshold sensitivity, indicating that moderate relations were seen between the SRT and PTC for frequency selective losses measured with low and mid frequency tones (correlations were 0.70 and 0.75, respectively). Further measures yielded the highest correlations to word discrimination scores in quiet. Measures of amplitude modulation and temporal integration generally manifested poor correlations to the speech performance.

Dresher and Fiepke (1985) related various automatic and psychoacoustic variables to speech perception in quiet and in noise for 21 hearing-impaired subjects from 13 to 20 years of age. The measure of speech perception was the SRT for sentences (Fiepke and Maiman, 1975). Speech perception in quiet was best predicted by the amount of loss, as represented generally by the mean audiometric tone thresholds, and specifically by the 500-Hz threshold. In contrast, automatic variables had little power for predicting speech perception in noise, which was best predicted by measures of gap detection and the critical ratio—believed to reflect indirectly the frequency resolution capabilities of the ear. These psychoacoustic measures accounted for about 70% of the variance among the subjects' hearing for speech in noise.

Fiepke and Wiley (1985) tested consonant recognition in quiet and PTCs for 3 pairs of two stimuli each, such as for audigrams showing either flat, low- or high-frequency losses. While a poor relation to low-frequency losses, the subject with poorer consonant recognition manifested a more abnormal PTC in the frequency region where the loss was greatest. Hence, pure tone threshold sensitivity appeared to be conserved with consonant recognition than did frequency resolution. Frequency selectivity and individual identification for synthetic, burstless /ga/ in a /ba, da, ga/ continuum to 2 kHz tone thresholds and frequency selectivity of a listener who generally showed reduced perception for /ga/. The optimal tone, of 1000 Hz in this study. While a moderate relation to /ga/ identification was found for the optimal tone, the frequency resolution required for the measures of 2 kHz frequency selectivity versus /ga/ varied considerably, as depicted in Figure 1. With few exceptions (e.g., Dorman, 1985) psychoacoustic and auditory performance are strongly, though variably, related among these studies of psychoacoustic versus speech perception in noise. Performing a total performance score, which is then analyzed for its relation to psychoacoustic data. Speech global score and group mean measures are gross measures of speech recognition and do not vary on a case-by-case basis in speech that may be imperceptible for a hearing-impaired listener. Listeners of temporal and spectral cues are available for use in recognition of phonemes, the hearing-impaired listener may rely exclusively on one type of cue, because other cues are incomprehensible. For example, in discrimination of final consonant voicing, some of our listeners seemed to depend primarily on the vowel duration cue since their performance was best reduced for consonant constellation cues or spectral cues in the vowel offset (Kellie et al., 1984). If a listener's speech perception is limited to use of only one type of cue, that information would seem more relevant to conventional analyses of speech and psychoacoustic performances. Underlying the effort to relate psychoacoustic performance and speech recognition is the assumption that psychoacoustic discrimination for a particular type of stimulus is associated with a similar mode of auditory processing for speech recognition. Yet few attempts have been made to examine given auditory abilities in relation to the use of particular types of acoustic patterns involved in speech recognition. The speech/psychosocial relations may be more easily determined if speech recognition is measured according to one of several classes of cues that contribute to phonemes distinctions, for example, temporal cues, dynamic spectral cues, or static spectral cues. Relative to these classes, then psychoacoustic performances for analogous stimuli could be examined (as well as for the more traditional types of psychoacoustic stimuli used for this purpose). The psychoacoustic performances found to relate most highly with the speech measures may be those that used acoustic stimuli resembling the critical speech cue patterns.

A study modeled after this approach would test consonant recognition according to articulatory features used in stimuli altered to contain only one type of cue per feature category. Thus, recognition of a given stimulus would depend only on the perceptibility for the listener of the single available cue per cue category. This approach could use the stimuli used by hearing-impaired listeners for consonant recognition. The protocol would select according to the dominant acoustic cues of the stimuli. An example, in a study of SRT use for voicing perception of initial consonants, the speech recognition of psychoacoustic performance would be indicated.

In the investigation reported here, we have employed a degraded spoken stimulus to determine whether hearing-impaired listeners for consonant recognition. Listeners are tested with different conditions of noise, tonal, and pitch cues, among which the different redundant cues have been varied. The consonant identification performance declines significantly for a given condition of cue deletion, which is then analyzed to the importance to perception.

The following text describes three experiments in which the relations were examined between psychoacoustic performance and consonant recognition, where both were measured by stimulus to require similar types of auditory processing.
Vowel Duration Discrimination VS USE For Consonant Vowel Identification

Some hearing-impaired listeners with severe/profound losses may rely predominantly on the vowel duration cue to distinguish voicing consonants (Revoile et al. 1993). To test this hypothesis, we presented a range of vowel durations to test recognition of final fricative voicing for severely/profoundly hearing-impaired (HI) listeners.

Method:

1. For each of the syllables /ba/, /ba/, /ba/, /ba/, two different spoken utterances were selected from a typical test syllable. The stimuli were composed of 16 repetitions of each of the four fricatives /b/, /d/, /g/, /k/, each preceded and followed by the vowel of the syllable. The stimuli were identical for each syllable.

2. The vowels and fricatives were synthesized using two simultaneous formant passes across that channel is similar in the /j/ and /w/ syllables. A third-order partial duration discrimination with a stop-like duration of 197 ms was tested at least 5 times for each listener, according to the procedure established for the final fricative voicing perception for the listener group averaged 68% (S.D.: 17.3). Among the other measures obtained were discrimination of vowel duration versus fricative voicing perception for the vowel group averaged 68% (S.D.: 17.3)

3. The vowel duration discrimination task was scored across all four fricatives and ranged from 35% to 98% among the listeners. The vowel duration discrimination versus fricative voicing perception for the /ba/ and /ba/ syllables for the /ba/ and /ba/ syllables was tested at least 5 times for each listener, according to the procedure established for the final fricative voicing perception for the /ba/ and /ba/ syllables.

4. The vowel duration discrimination task was scored across all four fricatives and ranged from 35% to 98% among the listeners. The vowel duration discrimination versus fricative voicing perception for the /ba/ and /ba/ syllables was tested at least 5 times for each listener, according to the procedure established for the final fricative voicing perception for the /ba/ and /ba/ syllables.

5. The vowel duration discrimination task was scored across all four fricatives and ranged from 35% to 98% among the listeners. The vowel duration discrimination versus fricative voicing perception for the /ba/ and /ba/ syllables was tested at least 5 times for each listener, according to the procedure established for the final fricative voicing perception for the /ba/ and /ba/ syllables.
tification tasks, the listeners' modulation thresholds were measured for detecting several AM stimuli. Four AM modulation conditions were used: 30 Hz with a carrier frequency of 1024 Hz. For three conditions, the carrier was modulated at a rate of 4 Hz, and for the fourth condition the modulation rate was 12 Hz. Two of the 4-Hz modulated tones were modulated sinusoidally, but differed in duration (500 ms versus 1000 ms). For the third modulation condition, the carrier was modulated by a square wave. In the following, these conditions are denoted as 3SN (4-Hz sinusoidal modulation), SQ4 (4-Hz square wave modulation), SM4 (4-Hz sine modulation extended in duration from 500 to 1000 ms), and SM12 (12-Hz sinusoidal modulation).

The procedure was a 3-interval, task similar to those described above, in which depth of modulation was varied adaptively in discrete logarithmic steps to locate the listener's threshold for detecting the presence of modulation. Results. Table I presents the thresholds obtained from each listener for the various stimulus conditions, three-frequency pure tone thresholds averaged (PTA) and average percent correct stop consonant identification (ID) scores for consonants in either stressed syllable position (Initial, Final, or Combined) and percent correct stop consonant identification (ID) scores for consonants in either stressed syllable position (Initial, Final, or Combined).

The modulation thresholds varied over a range of about 20 dB and were generally well correlated with both the pure tone thresholds and with the identification scores. For example, the correlation between PTAs and SM12 was 0.572 while the correlation between SM4 and SQ4 was 0.565. The measure most strongly related to consonant identification score was significant at p < 0.0001. Once this variable was included in the regression equation, no other variable produced a significant improvement in the prediction of identification performance.

These results suggest a moderately strong relationship between AM detection thresholds and interlocutive consonant identification, however, they must be considered with caution. First, it is clear from the regression analysis that variance associated with AM threshold is not independent of that associated with the three frequency averages. Secondly, the correlations were based on the small number of listeners and relatively wide range of hearing loss they exhibited; our population of listeners was less diverse, or our population of sentences more diverse, weaker correlations likely would have obtained. Finally, it is worth mentioning that the LPC voicing process used in this experiment may be thought of as setting a general for the speech. Consequently, the identification performance here is actually similar to a speech-in-noise test.

**SUMMARY**

Prediction of speech recognition abilities on the basis of auditory discrimination capacities should be tested using stimuli that represent the speech features which are used by the particular acoustic differentials of the psychoacoustic discrimination tests. The potential application of this approach was tested in three studies using psychoacoustic measures of 1) duration discrimination, 2) rate of up-ward transition, and 3) detection of amplitude modulation in the extended-duration AM stimulus. The results yielded generally modest correlations, suggesting that additional research is required prior to the successful development of a predictive relational model between psychoacoustic measures of impaired hearing and phoneme perception.

**REFERENCES**


