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THE CALIBRATION AND VALIDATION OF A TWO-ALTERNATIVE FORCED-CHOICE TEST FOR EVALUATING HEARING LOSS OF COCHLEAR ORIGIN

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This paper describes a two-alternative, forced-choice speech consonant discrimination test, which was designed for investigating the phoneme confusions most common for patients with hearing loss of cochlear origin. Experiments are described, which established normal baselines and investigated the reliability of the test using normal hearing subjects.

Pick et al. (1977) and others have established that patients with hearing loss of cochlear origin have impaired frequency resolution. An important extension of this research was to investigate how, if at all, this impaired frequency resolution affects speech discrimination. In an initial study using a test incorporating the Boothroyd (1967) iso-phonemic monosyllable word lists, it became clear that this test was not efficient enough for investigating specific phoneme confusions. It also became clear that, because of the much greater resistance of vowel phonemes to distortion (e.g. Owens et al., 1968), it was better to investigate vowel confusions in a separate experiment. The present paper deals with a test devised to investigate consonant confusions.

The Test

From the results of the initial tests using the Boothroyd lists, and from published results (e.g. Oyer & Doudna, 1959) a list of 25 phoneme pairs were selected, the discrimination of which appeared to be degraded in cochlear hearing loss. These pairs were: /t/-/s/, /k/-/g/, /b/-/t/, /p/-/t/, /b/-/d/, /p/-/d/, /t/-/g/, /t/-/k/, /d/-/g/, /p/-/k/, /b/-/g/, /b/-/k/, /θ/-/f/, /s/-/f/, /z/-/v/, /s/-/θ/, /n/-/m/, /r/-/w/, /v/-/b/, /v/-/d/, /dz/-/b/, /t/-/tʃ/, /d/-/tʃ/, /m/-/z/, /n/-/z/. These phonemeswere placed in CVC context as pairs which differed only in the target consonant using commonly-used words. Each test list of 25 words contained one target for each of the phoneme pairs, and the test was constructed so that in 5 consecutive lists there was usually a high probability of presentation of each target of the pair in the initial and final position of the word. The word lists were recorded by a male speaker in a Standard English accent in a room anechoic in the range 0.5-5kHz. A cuing lamp illuminated for 1s, at approximately 2s before the CVC word was spoken. The word lists were preceded by a short training test and instructions spoken by the same speaker.

It was hypothesised that the presence of competing noise on speech discrimination might be more likely to show the effects of impaired frequency resolution than speech discrimination in quiet, which might be more dependent upon audiogram shape. Hence, a continuous speech babble masker was constructed by mixing, at equal levels, the voices of three male speakers reading at approximately constant level. The resulting speech spectrum fitted within 8dB that reported by Byrne (1977) to be the average for 30 speakers.

The subject responded by circling the word on the list which he judged to most closely match that which he heard. The subject was instructed to read the next pair of words on the list before the cuing light was illuminated.

The Subjects

The 22 male and female subjects ranged in age from 18 to 25 years, and were mainly university undergraduates. Their audiograms were within normal limits. The tests were performed monaurally on the ear with the lower pure tone threshold and with contralateral masking using a suitable level of white noise.

Preliminary Experiment

Five of the subjects were used to establish complete speech audiograms in the absence of speech babble and also at three levels of speech babble: 67, 77, and 87dB SPL. It was decided that in the main experiment only the 75% correct region was to be studied in detail and the results of the preliminary experiment suggested that these tests should be conducted at 22, and 27dB SPL in the absence of masking noise, and at the following levels (speech test dB SPL, masker dB SPL): (63, 67), (72, 77), (78, 77), and (82, 97).

Main Experiment

The subjects were divided into groups so that the inter-, and intra-subject variation between tests and inter-test reliability could be assessed. Each subject was tested at two masker conditions, and received five tests at each level.

Results and discussion

Fig. 1 shows the percentage correct scores averaged over all subjects, for all of the experimental conditions, together with 95% confidence limits. The 75% correct points were obtained by interpolation/extrapolation and are shown in Table 1.

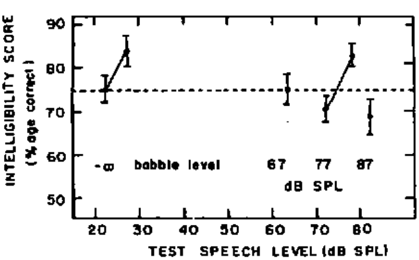

Fig. 1

It is interesting to note (although statistically non-significant) that for a 10dB increase in masker level for these normal-hearing subjects, an increase of the test word level of more than 10dB is required. This is consistant with the hypothesis that frequency resolution deteriorates at high levels for normal-hearing subjects (e.g. Pick, 1977) - assuming that frequency resolution is the limiting factor for discrimination under these conditions.

All of the tests, with one exception, proved to be statistically equivalent. No obvious reason for the exceptional list could be determined, either from examination of the recording or of the subjects responses.

One problem, which has been suggested byHaggard (verbal communication), is that the limitation of choice to two-alternatives might be too restrictive, and the subject might be using perceptual processes not closely related to those used in everyday speech perception. In an attempt to test this hypothesis, an analysis of the relative information transmitted to the subject was undertaken (using techniques similar to those used by Miller and Nicely, 1955). It must be noted, however, that this analysis cannot be compared easily with the results of Miller

Table 1

Babble Noise Level (dB SPL)	Estimated 75% correct speech level (dB SPL)	95% confidence limits (dB SPL)
$-\infty$	22.0	20.1 - 23.9
67	63.0	61.2 - 64.8
77	74.0	72.6 - 75.4
87	85.0	82.9 - 87.1

and Nicely, for even if the perceptual processes were identical, the test designs would lead to differences in information transmitted. For example, only a limited phoneme set was used, and only 67 of the possible 289 cells of the confusion matrix could be filled. The latter consideration, however, is not as serious as it appears, because these cells include very many of the high probability responses for normal-hearingsubjects. The analysis is valid for making comparison between conditions. Table 2 shows the relative information transmitted about all phonemes, voicing, stops/non-stops, affrication, and place.

Table 2: Comparison of relative information transmitted about linguistic features

Linguistic feature	experimental condition					
	Babble $-\infty$ Test word 22	$-\infty$ 27	67 63	77 72	77 78	87 82 dB SPL
All phonemes	0.71	0.74	0.72	0.69	0.79	0.69
Voicing	0.81	0.90	0.84	0.71	0.89	0.79
stop/non-stop	0.64	0.72	0.71	0.62	0.79	0.62
affrication	0.51	0.66	0.59	0.48	0.69	0.48
place	0.35	0.54	0.36	0.35	0.46	0.32

Bearing in mind the caveats given above, the relative information transmitted about voicing, affrication, and place fit quite closely to those of Miller and Nicely, whilst information transmitted about all phonemes, and about stops, is rather higher. However, the results, on the whole, suggest that a similar analysis mechanism is being used by our subjects, as in the experiments of Miller and Nicely.

Another result which is noteworthy in Table 2 is that, taking into account the overall information transmitted, there is a trend for information transmitted about certain features to decline slightly as the noise babble level is increased, possibly suggesting that these features are less detectable under those masking conditions.

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Conclusions

We conclude, apart from the one exceptional list, that Tests 1-10 of the two-alternative forced-choice test are equivalent, and of value for the purpose of examining consonant confusions in subjects with cochlear hearing loss.

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Footnote

[1]JHG now at Audiology Unit, Institute of Sound & Vibration Research, Southampton University. This work was done as part of JHG's final year project for his Bachelor's degree, under the supervision of GFP.

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