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*TNO-report*

TM-00-C020

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Title

Speech intelligibility and speech quality of a MELP speech coder in combination with a noise pre-processing system

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date

24 May 2000

Opdrachtgever            :   ..

Aantal pagina's          :   44        (incl. bijlagen,
                                        excl. distributielijst)

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Rep.No. TM-00-C020

TNO Human Factors
Soesterberg, The Netherlands

**Speech intelligibility and speech quality of a MELP speech coder in combination with a noise pre-processing system**

P.M.T. Smeele, E. Agterhuis and H.J.M. Steeneken

SUMMARY

The speech intelligibility and quality of a MELP[1] low bitrate speech coder (1200 bps) were investigated in an experiment, in which the speech coder was either combined with or without a noise pre-processing system. The central question to be addressed was to what extent the performance of the speech coder could be improved by adding a noise pre-processing system.

In the speech intelligibility test, participants were presented with CVC-words (consonant-vowel-consonant words) under fifteen different transmission conditions: three systems (speech coder, noise pre-processor, combination of speech coder and noise pre-processor) were tested for five noise conditions, i.e. a 'clean' condition (no additive noise), aircraft noise at 12 and 6 dB SNR, and vehicle noise at 12 and 6 dB SNR. For each transmission condition, word scores and individual phoneme scores for the initial consonant, vowel and the final consonant were obtained. These can be used for diagnostic purposes.
In the speech quality test, mean opinion scores (MOS) were obtained: participants rated the quality of short sentences on a five-point scale ranging from bad to excellent. The sentences were presented under similar transmission conditions as in the speech intelligibility test.

The results of both tests show that the performance of the MELP speech coder is affected by noise, as could be expected. Furthermore, its performance seems to depend on the fundamental frequency of the speaker's voice: word (intelligibility) and mean opinion (quality) scores for male speech generally are higher than for female speech. When the MELP speech coder is combined with the noise pre-processor used in this study the speech intelligibility and speech quality are significantly improved in case of low frequency noise (e.g. vehicle), but for high frequency noise (e.g. aircraft) improvements, if any, are found only when the noise level is high (6 dB SNR).

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[1] MELP: Mixed Excited Linear Prediction

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**Spraakverstaanbaarheid en spraakkwaliteit van een MELP-spraakcodeersysteem in combinatie met een ruisonderdrukkend systeem**

P.M.T. Smeele, E. Agterhuis en H.J.M. Steeneken

SAMENVATTING

De spraakverstaanbaarheid en kwaliteit van een MELP[2] 'low bitrate' spraakcodeersysteem (1200 bps) zijn onderzocht in een experiment waarin het spraakcodeersysteem met en zonder ruisonderdrukker voorkwam. De centrale vraag van dit onderzoek luidde in hoeverre de 'performance' van het spraakcodeersysteem door toevoeging van een ruisonderdrukker verbeterd kan worden.

In de verstaanbaarheidstest kregen luisteraars CVC-woorden (consonant-vocaal-consonant) aangeboden onder 15 verschillende transmissiecondities, nl. drie systemen (spraakcodeersysteem, ruisonderdrukker, spraakcodeersysteem met ruisonderdrukker) werden getest in vijf condities bestaande uit 'schone' spraak (geen ruis toegevoegd), spraak tegen een achtergrond van vliegtuiglawaai met signaal-ruis-verhoudingen van 12 en 6 dB en spraak tegen een achtergrond van voertuiglawaai met signaal-ruis-verhoudingen van 12 en 6 dB.
Voor iedere transmissieconditie zijn woordscores en individuele foneemscores (voor initiële consonant, vocaal en finale consonant) bepaald. Deze scores kunnen voor diagnostische doeleinden worden gebruikt.
In de kwaliteitstest zijn 'mean opinion scores' (MOS) bepaald: luisteraars beoordeelden de kwaliteit van korte zinnen op een vijfpunts-schaal van slecht tot uitstekend. De zinnen werden aangeboden onder dezelfde 15 transmissiecondities als in de verstaanbaarheidstest.

De resultaten van beide testen laten zien dat het MELP-spraakcodeersysteem ten gevolge van lawaai slechter presteert, zoals te verwachten was. De 'performance' van het systeem lijkt af te hangen van de grondfrequentie van de stem van de spreker: woordscores (verstaanbaarheid) en MOS-scores (kwaliteit) zijn over het algemeen hoger voor mannelijke sprekers dan voor vrouwelijke sprekers. Wanneer het spraakcodeersysteem gecombineerd wordt met de in deze studie onderzochte ruisonderdrukker, dan leidt dit tot een verbetering van zowel de verstaanbaarheid als de kwaliteit in geval van laagfrequente stoorsignalen (bv. voertuiglawaai), maar voor hoogfrequente stoorsignalen (bv. vliegtuiglawaai) treedt een verbetering slechts op bij een hoog lawaainiveau (6 dB signaal-ruis-verhouding).

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[2] MELP: Mixed Excited Linear Prediction

1       INTRODUCTION

The speech intelligibility and quality of the MELP[3] low bitrate speech coder (1200 bps) was determined in conditions with and without a noise pre-processing system. Also, the intelligibility and quality of the noise pre-processing system alone was determined. The coder and noise pre-processing system were tested in various transmission conditions, simulating practical adverse conditions, such as additive noise (e.g. caused by aircraft or vehicle).

2       MEASURING SPEECH INTELLIGIBILITY

**2.1     Participants**

Four female listeners (age between 21 and 35 years, normal hearing) participated in the speech intelligibility test. They were tested on five consecutive days, each day for approx. three hours including breaks, in two individual sessions (2 participants were tested simultaneously). The first day was used for training and the remaining days for actual testing. The participants were paid for their participation.

**2.2     Test materials**

The intelligibility was measured using CVC-words (consonant-vowel-consonant words) as described in Steeneken et al. (1990). Word lists consisting of 51 CVC-words were used as test materials. The distribution of the consonants and vowels in these lists are equally balanced (i.e. 17 initial consonants, 15 vowels and 11 final consonants appear in each list). Each word on the list was embedded in a carrier phrase.

Recordings were made of four male and four female speakers, each producing 15 different lists for a total of 120 unique word lists under good laboratory conditions (high-quality microphone, no ambient noise). The 15 lists for each speaker were then processed in such a way that they represent three pairs of five different transmission conditions: a 'clean' condition in which no noise was added, and four adverse conditions in which one of two types of noise (aircraft and vehicle) at one of two different signal-to-noise ratios were added (the noises were obtained from the NATO-RSG10 noise database 1989).

For each speaker, the 15 lists representing three pairs of five transmission conditions were recorded on CD-ROM. After this, the CD-ROM was processed by Tübitak-Uekae: one pair of five transmission conditions was processed by using the MELP speech coder, the second pair by using the noise pre-processing system and the third pair by using the combination of the speech coder with the noise pre-processing system. Table I illustrates the various conditions.

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[3] MELP: Mixed Excited Linear Prediction

Table I The 15 different transmission conditions used in the speech intelligibility test (SNR = signal-to-noise ratio, NPP = noise pre-processing).

| MELP speech coder | NPP system | MELP + NPP system |
|---|---|---|
| Clean | Clean | Clean |
| Aircraft noise, 12 dB SNR | Aircraft noise, 12 dB SNR | Aircraft noise, 12 dB SNR |
| Aircraft noise, 6 dB SNR | Aircraft noise, 6 dB SNR | Aircraft noise, 6 dB SNR |
| Vehicle noise, 12 dB SNR | Vehicle noise, 12 dB SNR | Vehicle noise, 12 dB SNR |
| Vehicle noise, 6 dB SNR | Vehicle noise, 6 dB SNR | Vehicle noise, 6 dB SNR |

## 2.3    Procedure

One random list was made out of the 120 (8 speakers * 15 conditions) processed word lists. Forty word lists were presented to the listening panel per day, in blocks of 10 to 15 lists with pauses between the blocks. The word lists presented on the first testing day were repeated on the fourth testing day.

Participants' task was to listen to the CVC-words, presented through headsets, and enter their response into the computer. The sound was set at a comfortable listening level (65 dB).

## 2.4    Analysis and results

The word score as well as the score for the initial consonants, the vowels, and the final consonants were determined. Results of the first testing day were not taken into the analysis, because of possible learning effects showing up. In Tables II and III the mean word scores for, respectively, male and female speakers are given, as well as the standard error.

Table II Mean CVC-word scores (mean) and standard error (se) for the 15 different transmission conditions for MALE speech (based on 4 speakers). Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| MALE SPEAKERS | **Coder** | | **NPP** | | **NPPCoder** | |
|---|---|---|---|---|---|---|
| **word score (%)** | *mean* | *se* | *mean* | *se* | *mean* | *se* |
| clean | 51.0 | 2.7 | 81.9 | 1.3 | 53.8 | 3.0 |
| aircraft, 12 dB SNR | 39.8 | 3.2 | 72.2 | 1.9 | 42.8 | 3.7 |
| aircraft, 6 dB SNR | 25.5 | 2.4 | 62.7 | 1.7 | 28.2 | 3.1 |
| vehicle, 12 dB SNR | 30.5 | 2.8 | 72.2 | 1.4 | 41.5 | 3.8 |
| vehicle, 6 dB SNR | 16.4 | 3.3 | 64.8 | 3.5 | 29.7 | 2.6 |

Table III Mean CVC-word scores (mean) and standard error (se) for the 15 different transmission conditions for FEMALE speech (based on 4 speakers). Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| FEMALE SPEAKERS | Coder | | NPP | | NPPCoder | |
|---|---|---|---|---|---|---|
| word score (%) | mean | se | mean | se | mean | se |
| clean | 38.8 | 1.7 | 80.3 | 1.2 | 39.1 | 2.0 |
| aircraft, 12 dB SNR | 24.8 | 2.7 | 66.4 | 2.9 | 24.9 | 2.7 |
| aircraft, 6 dB SNR | 13.0 | 2.5 | 52.1 | 4.2 | 19.6 | 3.3 |
| vehicle, 12 dB SNR | 17.4 | 2.0 | 66.7 | 4.1 | 31.4 | 2.8 |
| vehicle, 6 dB SNR | 9.2 | 2.1 | 58.6 | 4.1 | 26.6 | 1.9 |

The word scores for the male speakers generally are higher than for the female speakers. The analyses showed that this difference is significant ($p < 0.001$). This is most likely due to the lower fundamental frequency of the male speech, providing the speech coder with more harmonic components.

The central question is whether the noise pre-processor improves the performance of the speech coder. Statistical analyses (Analysis of Variance, ANOVA and Tukey-tests) indicated a significant improvement between the five Coder and NPPCoder conditions for male speech ($p < 0.001$) and for female speech ($p < 0.001$).

There appears to be a difference in the degree of noise cancellation for aircraft and vehicle noise. With vehicle (low frequency) noise, the pre-processor improves the performance of the speech coder to a larger extent than with aircraft (high frequency) noise. Comparing Coder with NPPCoder conditions, results of the analyses showed no improvement in case of aircraft noise ($p > 0.05$) and a significant improvement in case of vehicle noise ($p < 0.01$) for male speech. For female speech, an improvement was found with aircraft noise ($p < 0.05$) in case of a high noise level (6 dB) only, and a substantial improvement with vehicle noise ($p < 0.01$) regardless of the noise level. The pre-processor, therefore, is more effective for low frequency noise signals.

An interesting finding is that the differences in speech intelligibility between aircraft noise and vehicle noise conditions disappear when noise cancellation is applied. This effect is most clearly seen with male speakers.

Tables IV–VI present mean percent correctly identified initial consonants, vowels and final consonants (and standard error of mean) for male speech. In Tables VII–IX the results are given for female speech. As can be seen, the standard errors are small, indicating that the scores of the listeners do not diverge too much but fall within a well-defined range.

Table IV Mean initial consonant scores (mean) and standard error (se) for the 15 different transmission conditions for MALE speech (based on 4 speakers). Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| MALE SPEAKERS | Coder | | NPP | | NPPCoder | |
|---|---|---|---|---|---|---|
| **C initial score (%)** | *mean* | *se* | *mean* | *se* | *mean* | *se* |
| clean | 71.4 | 2.4 | 88.7 | 0.9 | 70.8 | 2.4 |
| aircraft, 12 dB SNR | 60.3 | 2.9 | 84.2 | 1.3 | 63.4 | 3.0 |
| aircraft, 6 dB SNR | 50.0 | 3.6 | 79.2 | 1.8 | 49.0 | 2.9 |
| vehicle, 12 dB SNR | 48.8 | 3.3 | 83.3 | 1.2 | 60.7 | 3.6 |
| vehicle, 6 dB SNR | 36.6 | 4.1 | 76.7 | 3.0 | 53.7 | 3.2 |

Table V Mean vowel scores (mean) and standard error (se) for the 15 different transmission conditions for MALE speech. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| MALE SPEAKERS | Coder | | NPP | | NPPCoder | |
|---|---|---|---|---|---|---|
| **Vowel score (%)** | *mean* | *se* | *mean* | *se* | *mean* | *se* |
| clean | 80.4 | 1.7 | 93.6 | 0.9 | 83.9 | 2.4 |
| aircraft, 12 dB SNR | 82.0 | 2.0 | 93.8 | 1.1 | 76.7 | 2.9 |
| aircraft, 6 dB SNR | 65.7 | 2.8 | 91.2 | 1.1 | 73.7 | 3.4 |
| vehicle, 12 dB SNR | 80.0 | 1.6 | 93.3 | 1.0 | 78.7 | 2.6 |
| vehicle, 6 dB SNR | 64.2 | 3.0 | 90.8 | 0.8 | 75.1 | 2.2 |

Table VI Mean final consonant scores (mean) and standard error (se) for the 15 different transmission conditions for MALE speech. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| MALE SPEAKERS | Coder | | NPP | | NPPCoder | |
|---|---|---|---|---|---|---|
| **C final score (%)** | *mean* | *se* | *mean* | *se* | *mean* | *se* |
| clean | 83.0 | 1.4 | 98.0 | 0.5 | 87.4 | 1.4 |
| aircraft, 12 dB SNR | 75.5 | 1.5 | 91.2 | 1.6 | 77.5 | 1.7 |
| aircraft, 6 dB SNR | 59.1 | 2.4 | 84.6 | 1.2 | 70.7 | 2.0 |
| vehicle, 12 dB SNR | 68.0 | 2.3 | 93.8 | 1.1 | 79.8 | 1.1 |
| vehicle, 6 dB SNR | 50.2 | 3.0 | 89.7 | 1.2 | 68.0 | 1.6 |

Table VII Mean initial consonant scores (mean) and standard error (se) for the 15 different transmission conditions for FEMALE speech (based on 4 speakers). Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| FEMALE SPEAKERS | Coder | | NPP | | NPPCoder | |
|---|---|---|---|---|---|---|
| **C initial score (%)** | *mean* | *se* | *mean* | *se* | *mean* | *se* |
| clean | 64.1 | 1.9 | 88.7 | 0.6 | 65.3 | 2.6 |
| aircraft, 12 dB SNR | 53.1 | 2.8 | 86.2 | 1.4 | 54.4 | 2.9 |
| aircraft, 6 dB SNR | 40.8 | 3.4 | 77.2 | 2.8 | 45.7 | 3.5 |
| vehicle, 12 dB SNR | 44.5 | 2.9 | 81.7 | 2.3 | 58.2 | 2.8 |
| vehicle, 6 dB SNR | 34.1 | 3.2 | 77.2 | 2.8 | 54.5 | 2.0 |

Table VIII Mean vowel scores (mean) and standard error (se) for the 15 different transmission conditions for FEMALE speech. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| FEMALE SPEAKERS | Coder | | NPP | | NPPCoder | |
|---|---|---|---|---|---|---|
| Vowel score (%) | mean | se | mean | se | mean | se |
| clean | 76.0 | 1.8 | 93.9 | 0.9 | 73.8 | 1.3 |
| aircraft, 12 dB SNR | 64.3 | 2.1 | 91.1 | 0.8 | 65.2 | 1.4 |
| aircraft, 6 dB SNR | 52.8 | 3.2 | 83.2 | 3.7 | 58.6 | 3.2 |
| vehicle, 12 dB SNR | 65.8 | 2.6 | 90.4 | 1.7 | 69.5 | 2.9 |
| vehicle, 6 dB SNR | 50.7 | 3.0 | 88.7 | 1.6 | 70.8 | 2.0 |

Table IX Mean final consonant scores (mean) and standard error (se) for the 15 different transmission conditions for FEMALE speech. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

| FEMALE SPEAKERS | Coder | | NPP | | NPPCoder | |
|---|---|---|---|---|---|---|
| C final score (%) | mean | se | mean | se | mean | se |
| clean | 76.8 | 1.9 | 94.6 | 0.8 | 74.5 | 1.1 |
| aircraft, 12 dB SNR | 57.7 | 3.0 | 84.2 | 1.9 | 64.0 | 2.5 |
| aircraft, 6 dB SNR | 42.9 | 3.0 | 74.6 | 2.6 | 57.0 | 3.4 |
| vehicle, 12 dB SNR | 52.5 | 2.1 | 86.9 | 2.6 | 72.7 | 1.9 |
| vehicle, 6 dB SNR | 36.8 | 3.7 | 80.4 | 2.4 | 59.3 | 3.3 |

Tables X–XV present the confusion matrices for the initial consonants and vowels in case of transmission through the MELP speech coder, noise pre-processor, or a combination of the speech coder and the noise pre-processor, respectively, for clean male speech (no noise added). Tables XVI–XXI for clean female speech. Initial consonants that are mainly confused (identification < 75%) are T, F, M, N, L, W, B, D, V and Z. The majority of V/F and Z/S-confusions were caused by two participants systematically responding the voiceless counterparts when hearing V and Z. Vowels that are confused (identification < 75%) are AU, EU, E, OO, OE, and U. Generally, for female speech more confusions occur than for male speech, as can be expected.

Table X  Confusion matrix for the initial consonants transmitted through the MELP speech coder, for CLEAN MALE speech.

| Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 39 | 2 | 1 | 2 | - | - | - | - | 1 | - | - | - | - | 2 | - | - | - | - | 1 | 48 | 81.3 |
| 2 T | 3 | 33 | 10 | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | 48 | 68.8 |
| 3 K | 1 | 2 | 43 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 48 | 89.6 |
| 4 F | - | - | - | 28 | - | 6 | - | - | - | - | - | - | - | - | - | - | 13 | - | 1 | 48 | 58.3 |
| 5 S | - | - | - | - | 45 | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | - | 48 | 93.8 |
| 6 G | - | - | - | 1 | - | 46 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 48 | 95.8 |
| 7 M | - | - | - | - | - | - | 23 | - | 15 | - | - | 2 | 8 | - | - | - | - | - | - | 48 | 47.9 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 7 | - | 35 | - | - | - | 5 | 1 | - | - | - | - | - | 48 | 72.9 |
| 10 L | - | - | - | - | - | - | - | - | 12 | 22 | 1 | 4 | 9 | - | - | - | - | - | - | 48 | 45.8 |
| 11 R | - | - | - | - | - | 1 | - | - | - | - | 44 | - | 3 | - | - | - | - | - | - | 48 | 91.7 |
| 12 W | - | - | - | - | - | - | - | - | - | - | 1 | 33 | 6 | 4 | 4 | - | - | - | - | 48 | 68.8 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | 48 | 100.0 |
| 14 H | - | - | - | - | - | 1 | - | - | - | - | - | 3 | - | 44 | - | - | - | - | - | 48 | 91.7 |
| 15 B | - | - | - | - | - | - | - | - | - | - | - | 13 | 2 | - | 32 | 1 | - | - | - | 48 | 66.7 |
| 16 D | - | - | - | - | - | - | - | - | - | - | - | 3 | 7 | - | 5 | 33 | - | - | - | 48 | 68.8 |
| 17 V | - | - | - | 24 | - | - | - | - | - | - | 1 | 2 | - | - | - | - | 21 | - | - | 48 | 43.8 |
| 18 Z | - | - | - | - | 25 | - | - | - | - | - | 1 | 1 | 7 | - | - | - | - | 14 | - | 48 | 29.2 |
| Confusion | 4 | 4 | 11 | 27 | 25 | 8 | 7 | 0 | 28 | 0 | 4 | 28 | 44 | 12 | 9 | 1 | 15 | 2 | 4 | 233 | |

Table XI  Confusion matrix for the vowels transmitted through the MELP speech coder, for CLEAN MALE speech.

| Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 46 | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 48 | 95.8 |
| 2 AU | 3 | 39 | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | 52 | 75.0 |
| 3 A | 1 | 2 | 93 | - | - | - | - | - | - | - | - | - | - | - | - | - | 96 | 96.9 |
| 4 EE | - | - | - | 40 | - | - | - | 2 | 6 | - | - | - | - | - | - | - | 48 | 83.3 |
| 5 IJ | - | - | - | - | 47 | - | - | - | 1 | - | - | - | - | - | - | - | 48 | 97.9 |
| 6 EU | - | - | - | - | - | 31 | - | - | - | - | - | - | 5 | - | 11 | 1 | 48 | 64.6 |
| 7 E | 1 | - | 2 | 9 | - | 1 | 52 | 2 | 16 | - | - | - | 1 | 4 | 8 | - | 96 | 54.2 |
| 8 IE | - | - | - | - | - | - | - | 44 | 1 | - | - | - | 3 | - | - | - | 48 | 91.7 |
| 9 I | - | - | - | - | - | - | 1 | 6 | 40 | - | - | - | - | - | 1 | - | 48 | 83.3 |
| 10 OO | - | - | 2 | - | - | - | - | - | - | 32 | - | 8 | - | - | 2 | - | 44 | 72.7 |
| 11 OE | - | - | - | - | - | - | - | - | - | 6 | 34 | 1 | 6 | - | - | 1 | 48 | 70.8 |
| 12 O | - | - | 2 | - | - | - | - | - | - | 1 | 7 | 38 | - | - | - | - | 48 | 79.2 |
| 13 UU | - | - | - | - | - | 1 | - | 7 | - | - | - | - | 39 | - | 1 | - | 48 | 81.3 |
| 14 UI | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 46 | - | 1 | 48 | 95.8 |
| 15 U | - | - | - | - | - | 2 | 1 | 2 | 4 | - | - | - | 4 | - | 35 | - | 48 | 72.9 |
| Confusion | 5 | 2 | 17 | 9 | 1 | 4 | 2 | 19 | 28 | 7 | 7 | 9 | 19 | 5 | 23 | 3 | 160 | |

Table XII  Confusion matrix for the initial consonants transmitted through the noise pre-processor, for CLEAN MALE speech.

| Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 2 T | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 3 K | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 4 F | - | - | - | 31 | - | - | - | - | - | - | - | - | - | - | - | - | 17 | - | - | 48 | 64.6 |
| 5 S | - | - | - | - | 38 | - | - | - | - | - | - | - | - | - | - | - | - | 10 | - | 48 | 79.2 |
| 6 G | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 7 M | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 10 L | - | - | - | - | - | - | - | - | - | 46 | - | - | - | - | - | - | - | - | 2 | 48 | 95.8 |
| 11 R | - | - | - | - | - | 1 | - | - | - | - | 47 | - | - | - | - | - | - | - | - | 48 | 97.9 |
| 12 W | - | - | - | 2 | - | - | - | - | - | - | - | 44 | - | - | - | - | 2 | - | - | 48 | 91.7 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | 48 | 100.0 |
| 14 H | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | 48 | 100.0 |
| 15 B | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | 48 | 100.0 |
| 16 D | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 47 | - | - | - | 48 | 97.9 |
| 17 V | - | - | - | 23 | - | - | - | - | - | - | - | 3 | - | - | - | - | 22 | - | - | 48 | 45.8 |
| 18 Z | - | - | - | - | 31 | - | - | - | - | - | - | - | - | - | - | - | - | 17 | - | 48 | 35.4 |
| Confusion | 0 | 1 | 0 | 25 | 31 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 19 | 10 | 2 | 92 | |

Table XIII Confusion matrix for the vowels transmitted through the noise pre-processor, for CLEAN MALE speech.

| Stimulus / Response | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 48 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 100.0 |
| 2 AU | – | 34 | 14 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 70.8 |
| 3 A | – | – | 96 | – | – | – | – | – | – | – | – | – | – | – | – | – | 96 | 100.0 |
| 4 EE | – | – | – | 44 | – | – | – | – | 4 | – | – | – | – | – | – | – | 48 | 91.7 |
| 5 IJ | – | – | – | – | 48 | – | – | – | – | – | – | – | – | – | – | – | 48 | 100.0 |
| 6 EU | – | – | – | – | – | 39 | – | – | – | – | – | – | – | – | 9 | – | 48 | 81.3 |
| 7 E | – | – | – | – | 5 | – | 90 | – | – | – | – | – | – | 1 | – | – | 96 | 93.8 |
| 8 IE | – | – | – | – | – | – | – | 44 | 4 | – | – | – | – | – | – | – | 48 | 91.7 |
| 9 I | – | – | – | 2 | – | – | 2 | – | 44 | – | – | – | – | – | – | – | 48 | 91.7 |
| 10 OO | – | – | – | – | – | – | – | – | – | 45 | – | 3 | – | – | – | – | 48 | 93.8 |
| 11 OE | – | – | – | – | – | – | – | – | – | – | 48 | – | – | – | – | – | 48 | 100.0 |
| 12 O | – | – | – | – | – | – | – | – | – | 1 | – | 47 | – | – | – | – | 48 | 97.9 |
| 13 UU | – | – | – | – | – | – | – | – | – | – | – | – | 47 | – | 1 | – | 48 | 97.9 |
| 14 UI | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | – | – | 48 | 100.0 |
| 15 U | – | – | – | – | – | 5 | – | – | – | – | – | – | – | – | 42 | 1 | 48 | 87.5 |
| Confusion | 0 | 0 | 14 | 2 | 5 | 5 | 2 | 0 | 8 | 1 | 0 | 3 | 0 | 1 | 10 | 1 | 52 | |

Table XIV Confusion matrix for the initial consonants transmitted through the MELP speech coder combined with the noise pre-processor, for CLEAN MALE speech.

| Stimulus / Response | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 32 | 7 | 2 | 1 | – | – | – | – | – | – | – | 1 | – | 2 | 3 | – | – | – | – | 48 | 66.7 |
| 2 T | – | 39 | 8 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 48 | 81.3 |
| 3 K | 4 | 2 | 41 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 48 | 85.4 |
| 4 F | – | – | 1 | 26 | – | 5 | – | – | – | – | – | – | – | 1 | – | – | 15 | – | – | 48 | 54.2 |
| 5 S | – | – | – | – | 40 | – | 1 | – | – | – | – | – | 1 | – | – | – | – | 6 | – | 48 | 83.3 |
| 6 G | – | – | – | 1 | – | 46 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 48 | 95.8 |
| 7 M | – | – | – | – | – | – | 38 | – | 7 | – | – | 2 | 1 | – | – | – | – | – | – | 48 | 79.2 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | –.– |
| 9 N | – | – | – | – | – | – | 12 | – | 27 | 3 | – | – | 5 | 1 | – | – | – | – | – | 48 | 56.3 |
| 10 L | – | – | – | – | – | – | 2 | – | 3 | 35 | 3 | 1 | 4 | – | – | – | – | – | – | 48 | 72.9 |
| 11 R | – | – | – | – | – | 2 | – | – | – | – | 39 | 2 | 1 | 4 | – | – | – | – | – | 48 | 81.3 |
| 12 W | – | – | – | – | – | – | 2 | – | – | 3 | 2 | 36 | – | – | – | 4 | 1 | – | – | 48 | 75.0 |
| 13 J | – | – | – | – | – | – | – | – | – | – | – | – | 46 | 2 | – | – | – | – | – | 48 | 95.8 |
| 14 H | – | – | – | – | – | 2 | – | – | – | – | 6 | 1 | – | 38 | – | – | 1 | – | – | 48 | 79.2 |
| 15 B | – | – | – | – | – | – | 2 | – | – | – | – | 14 | – | – | 30 | 2 | – | – | – | 48 | 62.5 |
| 16 D | – | – | – | 1 | – | – | – | – | 1 | 1 | – | 11 | 2 | – | 1 | 31 | – | – | – | 48 | 64.6 |
| 17 V | – | – | – | 18 | – | 2 | – | – | – | – | 1 | 6 | 1 | – | – | 1 | 19 | – | – | 48 | 39.6 |
| 18 Z | – | – | – | – | 24 | 2 | – | – | – | – | – | – | 6 | – | – | 1 | – | 15 | – | 48 | 31.3 |
| Confusion | 4 | 9 | 11 | 21 | 24 | 13 | 19 | 0 | 11 | 7 | 12 | 38 | 21 | 12 | 4 | 8 | 18 | 6 | 0 | 238 | |

Table XV Confusion matrix for the vowels transmitted through the MELP speech coder combined with the noise pre-processor, for CLEAN MALE speech.

| Stimulus / Response | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 46 | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 | – | 48 | 95.8 |
| 2 AU | 1 | 32 | 15 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 66.7 |
| 3 A | – | – | 93 | – | – | – | – | – | – | – | – | 3 | – | – | – | – | 96 | 96.9 |
| 4 EE | – | – | – | 37 | 1 | – | – | 4 | 6 | – | – | – | – | – | – | – | 48 | 77.1 |
| 5 IJ | – | – | – | 6 | 40 | – | 1 | – | 1 | – | – | – | – | – | – | – | 48 | 83.3 |
| 6 EU | – | – | – | – | – | 45 | – | – | – | – | – | – | – | – | 3 | – | 48 | 93.8 |
| 7 E | – | – | 1 | 7 | – | – | 58 | – | 27 | – | – | – | – | 2 | 1 | – | 96 | 60.4 |
| 8 IE | – | – | – | 1 | – | – | – | 43 | 3 | – | – | – | – | 1 | – | – | 48 | 89.6 |
| 9 I | – | – | – | 5 | – | – | – | 6 | 36 | – | – | – | – | 1 | – | – | 48 | 75.0 |
| 10 OO | – | 1 | – | – | – | – | – | – | 1 | 43 | – | 3 | – | – | – | – | 48 | 89.6 |
| 11 OE | – | – | – | – | – | – | – | – | – | 1 | 41 | 3 | 1 | – | 2 | – | 48 | 85.4 |
| 12 O | 2 | 1 | – | – | – | – | – | – | – | – | – | 45 | – | – | – | – | 48 | 93.8 |
| 13 UU | – | – | – | – | – | – | – | 2 | 2 | – | – | – | 44 | – | – | – | 48 | 91.7 |
| 14 UI | – | – | – | – | – | 1 | – | – | – | – | – | – | – | 47 | – | – | 48 | 97.9 |
| 15 U | – | – | – | – | – | 3 | – | – | 7 | – | – | 1 | 2 | – | 35 | – | 48 | 72.9 |
| Confusion | 3 | 2 | 16 | 19 | 1 | 4 | 1 | 12 | 47 | 1 | 0 | 10 | 3 | 4 | 8 | 0 | 131 | |

Table XVI Confusion matrix for the initial consonants transmitted through the MELP speech coder, for CLEAN FEMALE speech.

| Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 31 | 8 | 2 | 3 | - | - | - | - | - | - | - | - | - | 2 | - | - | 2 | - | - | 48 | 64.6 |
| 2 T | 5 | 33 | 10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 68.8 |
| 3 K | 1 | 1 | 46 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 95.8 |
| 4 F | - | 1 | - | 20 | - | 17 | - | - | - | - | - | - | - | - | - | - | 9 | 1 | - | 48 | 41.7 |
| 5 S | - | - | - | 2 | 42 | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 | - | 48 | 87.5 |
| 6 G | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 7 M | - | - | - | - | - | - | 20 | - | 13 | - | - | - | 14 | 1 | - | - | - | - | - | 48 | 41.7 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 6 | - | 24 | 1 | - | - | 17 | - | - | - | - | - | - | 48 | 50.0 |
| 10 L | - | - | - | - | - | - | - | - | 5 | 28 | - | 1 | 14 | - | - | - | - | - | - | 48 | 58.3 |
| 11 R | - | - | - | - | - | - | - | - | - | 5 | 36 | 2 | 2 | 1 | - | - | 2 | - | - | 48 | 75.0 |
| 12 W | - | - | - | - | 2 | - | - | - | - | 2 | - | 36 | 7 | - | - | - | 1 | - | - | 48 | 75.0 |
| 13 J | - | - | - | - | - | - | - | - | 1 | - | 3 | - | 44 | - | - | - | - | - | - | 48 | 91.7 |
| 14 H | - | - | - | - | - | - | - | - | - | - | - | - | 10 | 38 | - | - | - | - | - | 48 | 79.2 |
| 15 B | - | - | - | 3 | - | - | - | - | - | - | - | 12 | 4 | - | 23 | 5 | 1 | - | - | 48 | 47.9 |
| 16 D | - | 5 | 1 | - | 2 | - | - | - | - | 1 | - | 8 | 4 | - | 5 | 22 | - | - | - | 48 | 45.8 |
| 17 V | - | - | - | 22 | 1 | 5 | - | - | - | - | 1 | 2 | - | - | - | - | 17 | - | - | 48 | 35.4 |
| 18 Z | - | - | - | - | 33 | - | - | - | - | - | - | - | - | - | - | - | - | 15 | - | 48 | 31.3 |
| Confusion | 6 | 15 | 13 | 30 | 38 | 22 | 6 | 0 | 18 | 10 | 1 | 28 | 72 | 4 | 5 | 5 | 16 | 4 | 0 | 293 | |

Table XVII Confusion matrix for the vowels transmitted through the MELP speech coder, for CLEAN FEMALE speech.

| Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 42 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 48 | 87.5 |
| 2 AU | 2 | 30 | 15 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 48 | 62.5 |
| 3 A | 1 | 5 | 87 | - | - | - | - | - | - | - | - | 2 | - | 1 | - | - | 96 | 90.6 |
| 4 EE | - | - | - | 33 | - | 1 | 3 | - | 9 | - | - | - | - | - | 2 | - | 48 | 68.8 |
| 5 IJ | - | - | - | - | 46 | - | 1 | 1 | - | - | - | - | - | - | - | - | 48 | 95.8 |
| 6 EU | - | - | - | - | 1 | 37 | - | - | 2 | - | - | - | 1 | 2 | 5 | - | 48 | 77.1 |
| 7 E | 1 | - | - | - | 9 | 1 | 69 | - | 8 | - | - | - | 2 | - | 6 | - | 96 | 71.9 |
| 8 IE | - | - | - | - | - | - | - | 42 | 3 | - | - | 3 | - | - | - | - | 48 | 87.5 |
| 9 I | - | - | - | 3 | - | - | 1 | 6 | 31 | - | 1 | 3 | 3 | - | - | - | 48 | 64.6 |
| 10 OO | - | - | 1 | - | 2 | 1 | - | - | 1 | 30 | 3 | 8 | - | 1 | 1 | - | 48 | 62.5 |
| 11 OE | - | - | - | 2 | - | - | - | 1 | 1 | 1 | 35 | 2 | 2 | - | 4 | - | 48 | 72.9 |
| 12 O | - | - | 5 | - | - | - | - | - | 1 | 2 | 4 | 36 | - | - | - | - | 48 | 75.0 |
| 13 UU | - | - | - | - | - | 3 | - | 4 | - | - | - | - | 36 | - | 5 | - | 48 | 75.0 |
| 14 UI | 3 | - | - | - | 6 | 1 | - | - | - | - | - | - | - | 38 | - | - | 48 | 79.2 |
| 15 U | - | - | - | - | - | 6 | 1 | - | 1 | - | - | - | 12 | - | 28 | - | 48 | 58.3 |
| Confusion | 7 | 6 | 23 | 5 | 18 | 13 | 6 | 12 | 26 | 4 | 8 | 15 | 23 | 7 | 23 | 0 | 196 | |

Table XVIII Confusion matrix for the initial consonants transmitted through the noise pre-processor, for CLEAN FEMALE speech.

| Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 47 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 97.9 |
| 2 T | 1 | 47 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 97.9 |
| 3 K | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 4 F | - | - | - | 30 | - | - | - | - | - | - | - | - | - | - | - | - | 18 | - | - | 48 | 62.5 |
| 5 S | - | - | - | - | 44 | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | 48 | 91.7 |
| 6 G | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 7 M | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | - | - | 47 | - | - | - | - | - | - | - | - | - | 1 | 48 | 97.9 |
| 10 L | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 11 R | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 12 W | - | - | - | - | - | - | - | - | - | 1 | - | 47 | - | - | - | - | - | - | - | 48 | 97.9 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | 48 | 100.0 |
| 14 H | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | 48 | 100.0 |
| 15 B | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | 44 | - | - | - | - | 48 | 91.7 |
| 16 D | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 47 | - | - | - | 48 | 97.9 |
| 17 V | - | - | - | 24 | - | - | - | - | - | - | - | 2 | - | - | - | - | 22 | - | - | 48 | 45.8 |
| 18 Z | - | - | - | - | 35 | - | - | - | - | - | - | - | - | - | - | - | - | 13 | - | 48 | 27.1 |
| Confusion | 1 | 1 | 0 | 24 | 35 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 0 | 0 | 1 | 0 | 18 | 4 | 1 | 92 | |

Table XIX Confusion matrix for the vowels transmitted through the noise pre-processor, for CLEAN FEMALE speech.

| Response / Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 2 AU | - | 43 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 89.6 |
| 3 A | - | 1 | 95 | - | - | - | - | - | - | - | - | - | - | - | - | - | 96 | 99.0 |
| 4 EE | - | - | - | 45 | - | - | - | - | 2 | - | - | - | - | - | - | 1 | 48 | 93.8 |
| 5 IJ | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 6 EU | - | - | - | - | - | 44 | - | - | - | - | - | - | - | - | 4 | - | 48 | 91.7 |
| 7 E | - | - | - | - | 3 | - | 91 | - | - | - | - | - | - | 2 | - | - | 96 | 94.8 |
| 8 IE | - | - | - | 2 | - | - | - | 45 | 1 | - | - | - | - | - | - | - | 48 | 93.8 |
| 9 I | - | - | - | 3 | - | - | - | - | 45 | - | - | - | - | - | - | - | 48 | 93.8 |
| 10 OO | - | - | - | - | - | - | - | - | - | 38 | - | 10 | - | - | - | - | 48 | 79.2 |
| 11 OE | - | - | - | - | - | - | - | - | - | 1 | 40 | 7 | - | - | - | - | 48 | 83.3 |
| 12 O | - | - | 1 | - | - | - | - | - | 1 | 3 | - | 43 | - | - | - | - | 48 | 89.6 |
| 13 UU | - | - | - | - | - | - | - | - | - | - | - | - | 47 | - | 1 | - | 48 | 97.9 |
| 14 UI | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | 48 | 100.0 |
| 15 U | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | 46 | - | 48 | 95.8 |
| Confusion | 0 | 1 | 6 | 5 | 3 | 1 | 1 | 0 | 4 | 4 | 0 | 17 | 0 | 2 | 5 | 1 | 50 | |

Table XX Confusion matrix for the initial consonants transmitted through the MELP speech coder combined with the noise pre-processor, for CLEAN FEMALE speech.

| Response / Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 35 | 2 | 6 | 2 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 2 | - | 48 | 72.9 |
| 2 T | 3 | 38 | 6 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 48 | 79.2 |
| 3 K | - | 5 | 39 | - | - | - | - | - | - | - | - | 1 | 3 | - | - | - | - | - | - | 48 | 81.3 |
| 4 F | - | - | - | 21 | - | 9 | - | - | - | - | - | - | - | 1 | - | - | 17 | - | - | 48 | 43.8 |
| 5 S | - | - | - | - | 40 | - | - | - | - | - | - | - | - | - | - | - | 2 | 5 | 1 | 48 | 83.3 |
| 6 G | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 7 M | - | - | - | - | - | - | 16 | - | 21 | 2 | - | 1 | 7 | 1 | - | - | - | - | - | 48 | 33.3 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 9 | - | 27 | - | - | - | 11 | 1 | - | - | - | - | - | 48 | 56.3 |
| 10 L | - | - | - | - | - | - | 4 | - | 7 | 29 | - | 4 | 3 | 1 | - | - | - | - | - | 48 | 60.4 |
| 11 R | - | - | - | - | - | - | - | - | - | - | 46 | - | 2 | - | - | - | - | - | - | 48 | 95.8 |
| 12 W | - | - | - | 1 | - | - | - | - | - | 1 | 1 | 36 | 5 | - | 1 | - | 1 | 2 | - | 48 | 75.0 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | 4 | 44 | - | - | - | - | - | - | 48 | 91.7 |
| 14 H | - | - | - | - | - | - | 1 | - | - | - | - | - | 10 | 37 | - | - | - | - | - | 48 | 77.1 |
| 15 B | 3 | - | 1 | - | - | - | - | - | - | 3 | - | 18 | - | 1 | 21 | 1 | - | - | - | 48 | 43.8 |
| 16 D | - | 4 | - | - | 1 | - | - | - | - | - | - | 11 | - | - | 7 | 23 | 1 | 1 | - | 48 | 47.9 |
| 17 V | - | - | - | 23 | - | 4 | - | - | - | - | 1 | 4 | 1 | 1 | - | - | 14 | - | - | 48 | 29.2 |
| 18 Z | - | - | - | - | 25 | - | - | - | - | - | 1 | - | 2 | - | 1 | - | - | 19 | - | 48 | 39.6 |
| Confusion | 6 | 11 | 13 | 26 | 26 | 13 | 14 | 0 | 28 | 6 | 3 | 42 | 42 | 10 | 9 | 2 | 23 | 8 | 1 | 283 | |

Table XXI Confusion matrix for the vowels transmitted through the MELP speech coder combined with the noise pre-processor, for CLEAN FEMALE speech.

| Response / Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 47 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 48 | 97.9 |
| 2 AU | 1 | 34 | 9 | - | - | - | - | - | - | 4 | - | - | - | - | - | - | 48 | 70.8 |
| 3 A | 2 | 2 | 78 | - | - | 1 | - | - | - | - | 1 | 4 | - | 4 | 4 | - | 96 | 81.3 |
| 4 EE | - | - | - | 34 | - | - | 3 | 4 | 7 | - | - | - | - | - | - | - | 48 | 70.8 |
| 5 IJ | - | - | - | - | 44 | - | - | - | - | - | - | - | 3 | - | 1 | - | 48 | 91.7 |
| 6 EU | - | - | - | 5 | - | 37 | - | - | - | - | - | - | 4 | 1 | 1 | - | 48 | 77.1 |
| 7 E | - | - | - | 2 | 5 | - | 73 | 3 | 6 | - | - | 2 | - | 3 | 2 | - | 96 | 76.0 |
| 8 IE | - | - | - | - | - | - | - | 38 | 1 | - | 1 | 1 | 6 | - | 1 | - | 48 | 79.2 |
| 9 I | - | - | - | 7 | - | 1 | 1 | 10 | 25 | - | - | - | 2 | - | 2 | - | 48 | 52.1 |
| 10 OO | - | 2 | 1 | - | - | - | - | - | - | 34 | - | 11 | - | - | - | - | 48 | 70.8 |
| 11 OE | - | - | - | 1 | - | 1 | - | 4 | 1 | 1 | 28 | 5 | 3 | - | 4 | - | 48 | 58.3 |
| 12 O | - | - | - | - | - | - | - | - | - | 6 | - | 41 | - | - | 1 | - | 48 | 85.4 |
| 13 UU | - | - | - | - | - | 1 | - | 7 | - | - | 2 | - | 30 | - | 8 | - | 48 | 62.5 |
| 14 UI | - | 5 | 1 | - | 1 | 1 | - | - | - | - | - | - | - | 39 | 1 | - | 48 | 81.3 |
| 15 U | - | - | - | 2 | - | 2 | 1 | 3 | 6 | - | 1 | - | 12 | 1 | 20 | - | 48 | 41.7 |
| Confusion | 3 | 9 | 11 | 17 | 6 | 7 | 5 | 31 | 21 | 11 | 5 | 23 | 27 | 13 | 24 | 1 | 214 | |

# 3 MEASURING SPEECH QUALITY

## 3.1 Participants

Sixteen listeners (age between 18 and 30 years, normal hearing) participated in the speech quality test. They were tested for approx. 75 minutes including breaks. The participants were paid for their participation.

## 3.2 Test materials

The speech quality was measured using SRT-sentences (speech reception threshold sentences) as described in Plomp & Mimpen (1979) and Steeneken et al. (1990). Lists consisting of these sentences were used as test materials.

Recordings were made of four male and four female speakers. Each speaker produced a unique list and 15 copies of this list were created, for a total of 120 lists under good laboratory conditions (high-quality microphone, no ambient noise). The 15 lists for each speaker were then processed in the same manner as the test materials used in the speech intelligibility test, representing three pairs of five different transmission conditions: a 'clean' condition in which no noise was added, and four adverse conditions in which one of two types of noise (aircraft and vehicle) at one of two different signal-to-noise ratios were added.

For each speaker, the 15 processed lists were recorded on CD-ROM. After this, the CD-ROM was processed by Tübitak-Uekae: one pair of five transmission conditions was processed by using the MELP speech coder, the second pair by using the noise pre-processing system and the third pair by using the combination of the speech coder with the noise pre-processing system. After processing the same 15 transmission conditions as in the speech intelligibility test were obtained (see Table I).

## 3.3 Procedure

Hundred-and-twenty (8 speakers * 15 conditions) processed sentence lists were presented to the listeners, in blocks of 40 lists with pauses between the blocks. Sixteen listeners were tested in five sessions (per session 3 to 4 participants simultaneously), using a new random list in each session. Prior to testing, a practice list of 15 sentence lists containing examples of the entire quality range was given.

Participants' task was to listen to the sentences, presented through headsets, and to rate the quality of the speech on a five-point scale (i.e. bad, poor, fair, good, excellent). They entered their response onto response sheets. The sound was set at a comfortable listening level (65 dB).

## 3.4 Analysis and results

Participants' quality judgements were analysed and Mean Opinion Scores (MOS) were calculated for each transmission condition. Figure 1 illustrates MOS scores for the 15 different

transmission conditions for male and female speakers (averaged over 4 speakers) separately, and averaged over all speakers.
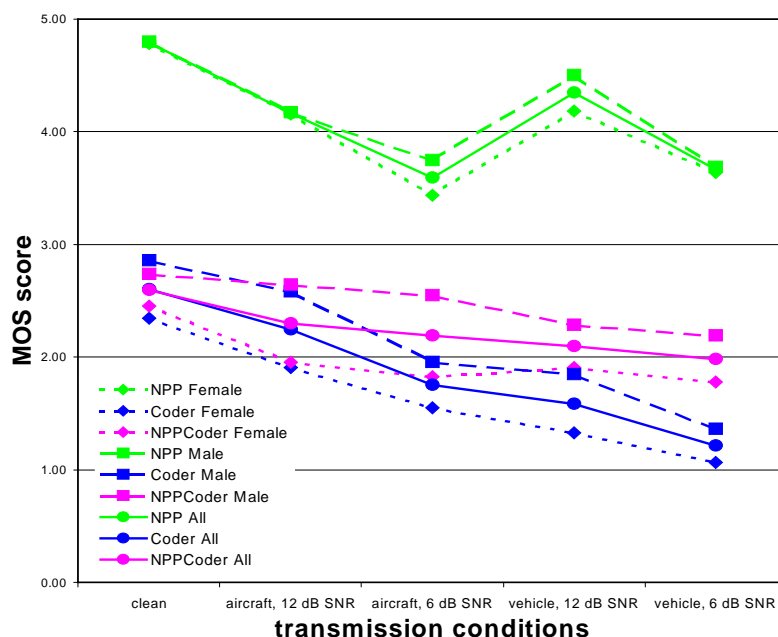


Fig. 1 MOS scores for the 15 different transmission conditions for MALE and FEMALE speakers, and averaged over ALL speakers. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor, SNR = signal-to-noise ratio.

The statistical analyses (ANOVA, Tukey-tests) show similar results for MOS scores as was found for the CVC-word scores.

The MOS scores for the male speakers generally are higher than for the female speakers ($p<0.001$). Participants rated the quality of both male and female speech significantly higher ($p<0.002$) when the speech coder was combined with the noise pre-processor than without.

Also for MOS scores, a difference in the degree of noise cancellation for aircraft and vehicle noise was found. Comparing Coder with NPPCoder conditions, results of the analyses showed almost no effects in case of aircraft noise ($p>0.05$) and a substantial improvement in case of vehicle noise ($p<0.01$) for both male and female speech.

## 4    CORRELATION BETWEEN SPEECH INTELLIGIBILITY AND SPEECH QUALITY SCORES

The quality ratings (MOS scores) appear to very nicely correspond to the CVC-word scores. The scatter diagram in Figures 2, 3 and 4 illustrate the relation between the scores from both tests, for male, female and all speakers, respectively (averaged over speakers). The correlation is $r=0.969$ for male, $r=0.989$ for female, and $r=0.983$ for all speakers (regression analysis Pearson's r, $p<0.001$).
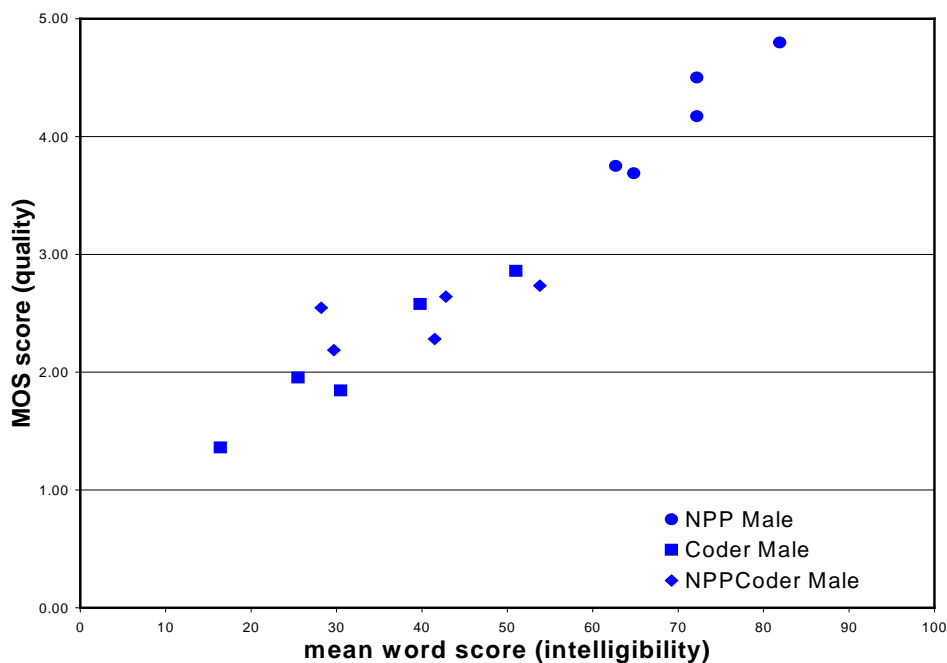
Fig. 2 Correlation between mean CVC-word scores (speech intelligibility) and Mean Opinion Scores (speech quality) for the 15 different transmission conditions for MALE speakers. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor.
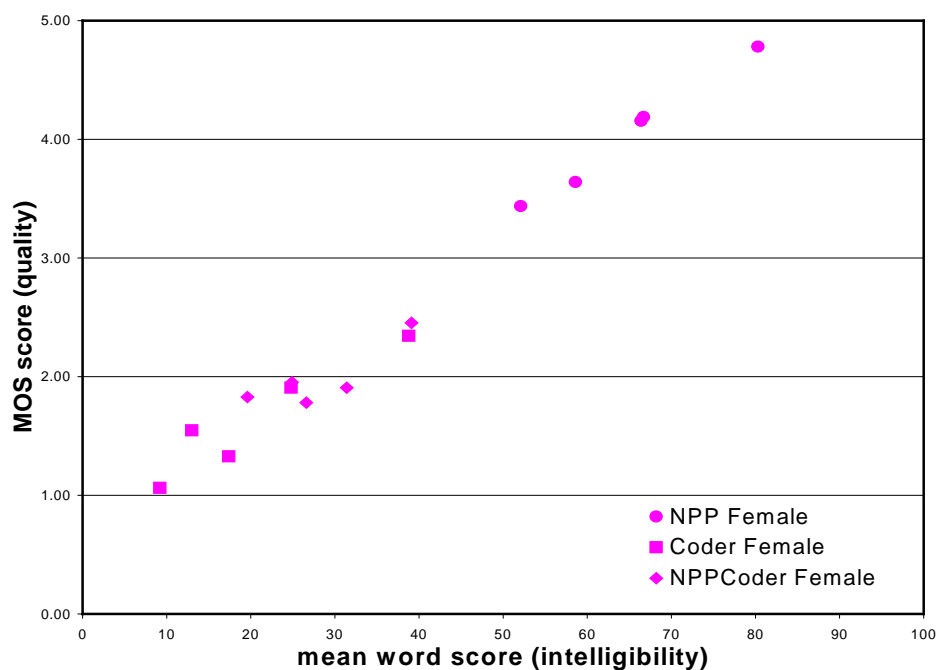


Fig. 3 Correlation between mean CVC-word scores (speech intelligibility) and Mean Opinion Scores (speech quality) for the 15 different transmission conditions for FEMALE speakers. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor.
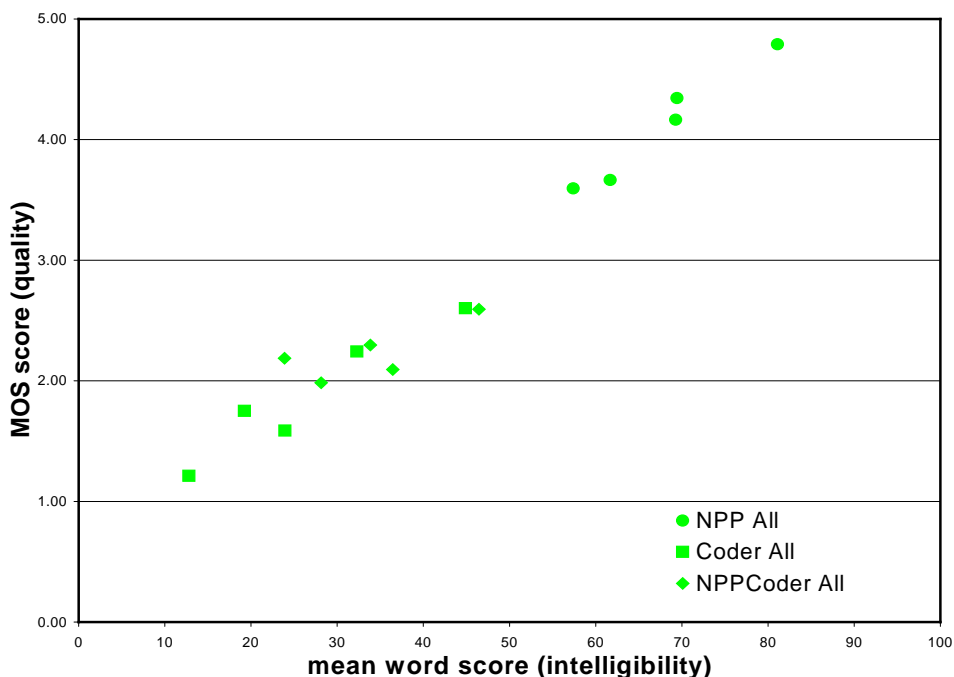
Fig. 4 Correlation between mean CVC-word scores (speech intelligibility) and Mean Opinion Scores (speech quality) for the 15 different transmission conditions averaged over ALL speakers. Coder = MELP speech coder, NPP = noise pre-processor, NPPCoder = speech coder combined with the noise pre-processor.

## 5    DICUSSION AND CONCLUSIONS

The performance of the MELP speech coder is affected by noise, as could be expected. Furthermore, its performance seems to depend on the fundamental frequency of the speaker's voice: word (intelligibility) and mean opinion (quality) scores for male speech generally are higher than for female speech. The central question of this study was to investigate whether the performance of the speech coder could be improved by adding a noise pre-processing system. When the MELP speech coder is combined with the noise pre-processor used in this study the speech intelligibility and speech quality are significantly improved in case of low frequency noise (e.g. vehicle), but for high frequency noise (e.g. aircraft) improvements, if any, are found only when the noise level is high (6 dB SNR).

The present study also showed a very high correlation between CVC-word scores and MOS scores, which may indicate that intelligibility is an important factor when people are judging speech quality.

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Soesterberg, 24 May 2000

Dr. P.M.T. Smeele
(First author, Project leader)

APPENDIX

## Confusion matrices for MALE (Tables A.1–12) and FEMALE (Tables A.13–24) speakers in the noise conditions

Table A.1 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for aircraft noise at 6 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 21 | – | 6 | 6 | – | 2 | 1 | – | – | – | 2 | 1 | 1 | 1 | – | – | 7 | – | – | 48 | 43.8 |
| 2 T | 4 | 30 | 3 | 3 | – | 3 | – | – | – | – | – | – | – | 2 | – | 1 | 2 | – | – | 48 | 62.5 |
| 3 K | 1 | 2 | 28 | 3 | – | 5 | – | – | – | – | 1 | 1 | 3 | 2 | – | – | 1 | – | 1 | 48 | 58.3 |
| 4 F | 5 | – | 2 | 16 | – | 9 | – | – | 1 | – | – | 1 | 2 | 2 | 1 | 2 | 7 | – | – | 48 | 33.3 |
| 5 S | – | – | – | – | 41 | 2 | – | – | – | – | – | – | – | – | 1 | – | – | – | 4 | 48 | 85.4 |
| 6 G | 1 | – | 4 | 5 | – | 32 | – | – | – | – | – | – | – | – | 2 | – | – | 4 | – | 48 | 66.7 |
| 7 M | 1 | – | – | – | 1 | – | 26 | – | 16 | – | – | – | 1 | – | – | 1 | – | 1 | 1 | 48 | 54.2 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | – | – | – | 11 | – | 21 | 2 | – | – | 12 | 1 | – | 1 | – | – | – | 48 | 43.8 |
| 10 L | – | – | – | – | – | – | 4 | – | 10 | 19 | 2 | 5 | 8 | – | – | – | – | – | – | 48 | 39.6 |
| 11 R | – | – | – | – | – | 2 | – | – | – | 1 | 28 | 5 | 4 | 4 | 1 | 3 | – | – | – | 48 | 58.3 |
| 12 W | – | – | – | – | – | – | 2 | – | 4 | 4 | 7 | 18 | 4 | 7 | 1 | 1 | – | – | – | 48 | 37.5 |
| 13 J | – | – | – | – | – | – | – | – | 4 | 3 | – | 5 | 35 | 1 | – | – | – | – | – | 48 | 72.9 |
| 14 H | – | – | 2 | – | – | – | 2 | – | 1 | 1 | 2 | 2 | 5 | 29 | – | 3 | 1 | – | – | 48 | 60.4 |
| 15 B | 1 | – | – | 2 | – | 1 | 1 | – | – | 1 | 2 | 7 | 3 | 5 | 22 | 2 | 1 | – | – | 48 | 45.8 |
| 16 D | – | 1 | 1 | 2 | 2 | – | – | – | 2 | – | 2 | 2 | 6 | 1 | 2 | 24 | 2 | 1 | – | 48 | 50.0 |
| 17 V | 4 | 1 | – | 9 | – | 2 | – | – | – | – | 5 | 2 | 4 | 4 | 4 | 5 | 8 | – | – | 48 | 16.7 |
| 18 Z | – | 3 | – | 1 | 26 | 1 | – | – | – | – | 2 | – | 3 | 1 | – | 1 | – | 10 | – | 48 | 20.8 |
| Confusion | 17 | 7 | 18 | 31 | 29 | 27 | 21 | 0 | 38 | 12 | 25 | 31 | 56 | 34 | 9 | 20 | 25 | 6 | 2 | 408 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 45 | – | 1 | – | – | – | – | – | – | – | – | – | – | 2 | – | – | 48 | 93.8 |
| 2 AU | 3 | 30 | 15 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 62.5 |
| 3 A | 2 | – | 91 | – | – | – | 1 | – | 1 | – | – | 1 | – | – | – | – | 96 | 94.8 |
| 4 EE | – | – | – | 20 | – | 3 | 2 | 4 | 13 | – | 3 | – | 1 | 1 | 1 | – | 48 | 41.7 |
| 5 IJ | – | – | 1 | – | 42 | – | – | – | 1 | 1 | – | – | – | 3 | – | – | 48 | 87.5 |
| 6 EU | 2 | – | – | – | – | 29 | 1 | 1 | – | 1 | – | 2 | 1 | 1 | 10 | – | 48 | 60.4 |
| 7 E | – | – | – | – | 4 | – | 61 | 4 | 10 | – | 2 | 4 | 4 | 4 | 3 | – | 96 | 63.5 |
| 8 IE | – | – | – | – | – | – | – | 35 | 2 | – | 3 | – | 6 | – | 2 | – | 48 | 72.9 |
| 9 I | – | – | – | 3 | 1 | – | 5 | 21 | 14 | – | – | – | 2 | – | 2 | – | 48 | 29.2 |
| 10 OO | – | 6 | 3 | – | – | – | 1 | – | 1 | 13 | 2 | 19 | 2 | – | 1 | – | 48 | 27.1 |
| 11 OE | – | – | – | – | – | – | – | 11 | 3 | – | 24 | – | 7 | – | 1 | 2 | 48 | 50.0 |
| 12 O | – | 1 | 2 | – | – | – | 1 | – | 3 | 1 | 2 | 38 | – | – | – | – | 48 | 79.2 |
| 13 UU | – | – | – | – | – | 1 | – | 10 | 1 | – | 4 | – | 32 | – | – | – | 48 | 66.7 |
| 14 UI | 2 | – | – | – | 3 | 1 | 5 | – | – | – | – | – | – | 37 | – | – | 48 | 77.1 |
| 15 U | – | – | – | – | – | 3 | – | 2 | 5 | 1 | 1 | 6 | 5 | – | 25 | – | 48 | 52.1 |
| Confusion | 9 | 7 | 22 | 3 | 8 | 8 | 16 | 53 | 40 | 4 | 17 | 32 | 28 | 11 | 20 | 2 | 280 | |

Table A.2 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for aircraft noise at 12 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 30 | 2 | 1 | 3 | - | - | - | - | - | 1 | - | 2 | 1 | 5 | - | - | 3 | - | - | 48 | 62.5 |
| 2 T | 4 | 27 | 5 | 3 | - | 1 | - | - | - | 1 | - | - | 2 | 2 | - | 3 | - | - | - | 48 | 56.3 |
| 3 K | 7 | - | 34 | - | - | 2 | - | - | - | - | - | - | 1 | 4 | - | - | - | - | - | 48 | 70.8 |
| 4 F | 3 | 1 | 1 | 17 | - | 8 | - | - | - | - | - | - | 1 | 2 | - | - | 14 | 1 | - | 48 | 35.4 |
| 5 S | - | 1 | - | - | 42 | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | 48 | 87.5 |
| 6 G | - | - | 2 | 1 | - | 33 | - | - | - | 1 | 1 | 1 | 1 | 5 | 1 | - | 2 | - | - | 48 | 68.8 |
| 7 M | - | - | - | - | - | - | 29 | - | 10 | - | - | 1 | 4 | 3 | 1 | - | - | - | - | 48 | 60.4 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 6 | - | 30 | 2 | 1 | 2 | 6 | - | - | - | - | - | 1 | 48 | 62.5 |
| 10 L | - | - | - | 1 | - | - | 2 | - | 7 | 30 | 2 | 1 | 5 | - | - | - | - | - | - | 48 | 62.5 |
| 11 R | 1 | - | - | 3 | - | - | - | - | - | 1 | 32 | 3 | 3 | 3 | 1 | 1 | - | - | - | 48 | 66.7 |
| 12 W | - | - | - | - | - | 1 | 1 | - | 2 | 2 | 1 | 38 | 1 | - | 2 | - | - | - | - | 48 | 79.2 |
| 13 J | - | - | - | - | - | - | 1 | - | 1 | 1 | - | 3 | 40 | - | - | 1 | - | 1 | - | 48 | 83.3 |
| 14 H | - | - | 1 | - | - | - | 1 | - | 1 | 2 | 2 | - | 1 | 39 | - | 1 | - | - | - | 48 | 81.3 |
| 15 B | 1 | 1 | 1 | - | - | - | - | - | - | 1 | - | 16 | 1 | 1 | 25 | - | 1 | - | - | 48 | 52.1 |
| 16 D | - | - | - | 2 | - | - | - | - | 1 | - | 4 | 6 | 1 | - | 6 | 26 | 2 | - | - | 48 | 54.2 |
| 17 V | - | - | - | 15 | - | 4 | - | - | 2 | - | 4 | 10 | 3 | 2 | - | - | 8 | - | - | 48 | 16.7 |
| 18 Z | - | - | 1 | - | 29 | - | - | - | - | - | - | - | 4 | 1 | - | 1 | - | 12 | - | 48 | 25.0 |
| Confusion | 16 | 5 | 12 | 28 | 29 | 16 | 11 | 0 | 24 | 12 | 15 | 45 | 35 | 28 | 11 | 7 | 22 | 7 | 1 | 324 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 46 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 95.8 |
| 2 AU | - | 41 | 5 | - | - | - | 1 | - | - | - | - | - | - | 1 | - | - | 48 | 85.4 |
| 3 A | 2 | - | 93 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 96 | 96.9 |
| 4 EE | - | - | - | 32 | - | - | 1 | 5 | 10 | - | - | - | - | - | - | - | 48 | 66.7 |
| 5 IJ | - | - | - | 1 | 39 | - | 7 | - | 1 | - | - | - | - | - | - | - | 48 | 81.3 |
| 6 EU | - | - | - | 3 | - | 32 | 2 | - | - | - | - | - | 4 | - | 7 | - | 48 | 66.7 |
| 7 E | - | - | 2 | - | 3 | - | 83 | - | 7 | - | - | 1 | - | - | - | - | 96 | 86.5 |
| 8 IE | - | - | - | - | - | - | - | 46 | - | - | - | 2 | - | - | - | - | 48 | 95.8 |
| 9 I | - | - | - | 2 | - | - | 3 | 7 | 35 | - | - | - | - | - | 1 | - | 48 | 72.9 |
| 10 OO | - | 5 | 3 | - | 1 | - | - | - | - | 24 | 5 | 9 | - | - | 1 | - | 48 | 50.0 |
| 11 OE | - | - | - | - | - | - | - | 2 | 3 | - | 34 | 1 | 8 | - | - | - | 48 | 70.8 |
| 12 O | - | - | 5 | - | - | - | - | - | - | 2 | 2 | 39 | - | - | - | - | 48 | 81.3 |
| 13 UU | - | - | - | - | - | - | 1 | 6 | 1 | - | 1 | - | 39 | - | - | - | 48 | 81.3 |
| 14 UI | - | - | - | - | - | 2 | 1 | - | - | - | - | - | - | 44 | - | 1 | 48 | 91.7 |
| 15 U | - | - | - | - | - | 2 | - | - | 4 | - | - | - | - | - | 42 | - | 48 | 87.5 |
| Confusion | 2 | 6 | 16 | 6 | 4 | 4 | 16 | 20 | 26 | 2 | 8 | 11 | 14 | 2 | 9 | 1 | 147 | |

Table A.3 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for vehicle noise at 6 dB SNR, MALE speech.

| Response / Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 7 | 3 | 2 | 7 | - | 2 | - | - | - | 5 | - | 2 | - | 6 | 3 | 7 | 4 | - | - | 48 | 14.6 |
| 2 T | 2 | 14 | 8 | 7 | 1 | 2 | - | - | - | - | 1 | - | - | 3 | - | 2 | 7 | 1 | - | 48 | 29.2 |
| 3 K | 3 | 1 | 21 | 3 | 1 | 6 | - | - | 1 | - | - | - | 5 | - | 3 | 3 | 1 | - | - | 48 | 43.8 |
| 4 F | 5 | 2 | 2 | 17 | - | 5 | - | - | - | 1 | - | 1 | 1 | 5 | 1 | - | 7 | - | 1 | 48 | 35.4 |
| 5 S | - | - | - | - | 38 | 5 | - | - | - | - | - | - | - | - | - | - | 1 | 4 | - | 48 | 79.2 |
| 6 G | 1 | - | 4 | 1 | - | 34 | - | - | - | - | 2 | - | 1 | 2 | - | - | 2 | - | 1 | 48 | 70.8 |
| 7 M | 2 | - | - | 1 | 1 | - | 21 | - | 4 | 2 | 3 | 1 | 6 | 5 | 1 | - | 1 | - | - | 48 | 43.8 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | 1 | 1 | 1 | 1 | 6 | 5 | - | 13 | 2 | - | - | 8 | 3 | - | 4 | - | - | 3 | 48 | 27.1 |
| 10 L | 1 | - | - | - | - | 2 | 2 | - | 3 | 23 | 8 | 2 | 5 | 1 | 1 | - | - | - | - | 48 | 47.9 |
| 11 R | 2 | - | 2 | 3 | - | 4 | 2 | - | 2 | - | 17 | 4 | 3 | 6 | 2 | - | 1 | - | - | 48 | 35.4 |
| 12 W | 6 | 3 | 1 | 6 | 1 | - | - | - | - | 4 | 5 | 13 | 2 | 5 | - | - | 1 | - | 1 | 48 | 27.1 |
| 13 J | 1 | - | 1 | 1 | - | 6 | - | - | 1 | - | 1 | 1 | 29 | 3 | - | 1 | - | 1 | 2 | 48 | 60.4 |
| 14 H | 1 | 1 | 4 | 3 | 1 | 8 | 1 | - | 3 | - | 1 | - | 2 | 20 | 1 | - | 1 | - | 1 | 48 | 41.7 |
| 15 B | 9 | - | 6 | 7 | 1 | 2 | 1 | - | - | 3 | 1 | 3 | 2 | 3 | 7 | 1 | 2 | - | - | 48 | 14.6 |
| 16 D | 1 | 3 | 2 | 3 | 2 | 4 | - | - | - | 1 | 1 | - | 6 | 5 | 1 | 15 | 3 | - | 1 | 48 | 31.3 |
| 17 V | 2 | 1 | 8 | 9 | 1 | 3 | - | - | 1 | - | 4 | 4 | 1 | 7 | 1 | 1 | 4 | - | 1 | 48 | 8.3 |
| 18 Z | - | - | 1 | - | 27 | 7 | - | - | - | - | 1 | - | 2 | - | - | 3 | 1 | 6 | - | 48 | 12.5 |
| Confusion | 36 | 15 | 42 | 52 | 37 | 62 | 11 | 0 | 15 | 18 | 28 | 18 | 44 | 54 | 14 | 22 | 32 | 6 | 11 | 517 | |

| Response / Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 31 | - | 9 | - | - | - | 1 | - | - | - | - | - | - | - | 6 | 1 | 48 | 64.6 |
| 2 AU | 3 | 15 | 28 | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 48 | 31.3 |
| 3 A | 2 | 1 | 90 | - | - | - | - | 1 | - | - | - | - | - | 2 | - | - | 96 | 93.8 |
| 4 EE | - | - | - | 18 | - | 1 | 3 | 7 | 14 | - | - | - | 4 | - | 1 | - | 48 | 37.5 |
| 5 IJ | - | - | - | - | 40 | - | 6 | - | - | - | - | 1 | - | 1 | - | - | 48 | 83.3 |
| 6 EU | - | - | - | - | - | 36 | - | - | - | 2 | - | - | 2 | 1 | 3 | - | 44 | 81.8 |
| 7 E | - | 1 | 3 | 1 | 5 | - | 57 | 7 | 11 | - | 1 | 1 | 2 | 4 | 2 | - | 96 | 59.4 |
| 8 IE | 1 | - | 1 | 1 | - | - | 1 | 33 | 1 | - | 5 | 1 | 2 | - | 2 | - | 48 | 68.8 |
| 9 I | - | - | - | 3 | 1 | - | 3 | 8 | 24 | - | 4 | - | 1 | 1 | 2 | 1 | 48 | 50.0 |
| 10 OO | - | 3 | 4 | - | - | - | - | - | - | 16 | 1 | 22 | - | - | 1 | 1 | 48 | 33.3 |
| 11 OE | - | 2 | - | 1 | - | 1 | - | 6 | 1 | 2 | 16 | 2 | 11 | - | 2 | 4 | 48 | 33.3 |
| 12 O | - | - | 13 | - | - | - | - | - | 1 | 2 | 1 | 31 | - | - | - | - | 48 | 64.6 |
| 13 UU | 1 | 1 | - | - | - | - | - | 2 | 1 | - | 1 | - | 37 | - | 3 | 2 | 48 | 77.1 |
| 14 UI | 2 | - | - | - | 2 | 2 | 1 | - | - | - | - | - | - | 45 | - | - | 52 | 86.5 |
| 15 U | - | - | - | - | - | 1 | 1 | 1 | 1 | - | - | 1 | 8 | - | 35 | - | 48 | 72.9 |
| Confusion | 9 | 8 | 58 | 6 | 8 | 5 | 16 | 32 | 30 | 6 | 13 | 28 | 30 | 13 | 19 | 11 | 292 | |

Table A.4 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for vehicle noise at 12 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 14 | - | 4 | 8 | - | 1 | - | - | 1 | 1 | 1 | 4 | 3 | 3 | 4 | 1 | 2 | - | 1 | 48 | 29.2 |
| 2 T | 3 | 13 | 5 | 4 | - | 4 | - | - | - | 1 | 1 | 2 | 3 | 3 | - | 4 | 5 | - | - | 48 | 27.1 |
| 3 K | 5 | 3 | 17 | 1 | - | 8 | - | - | - | - | 1 | 1 | 5 | 1 | 1 | 3 | 2 | - | - | 48 | 35.4 |
| 4 F | 1 | - | 1 | 21 | 1 | 6 | - | - | - | - | - | - | 1 | - | - | - | 17 | - | - | 48 | 43.8 |
| 5 S | - | - | - | - | 42 | - | - | - | - | - | - | - | - | - | - | - | 1 | 5 | - | 48 | 87.5 |
| 6 G | - | 1 | - | 3 | 1 | 35 | - | - | - | - | - | - | - | - | 6 | - | - | 1 | 1 | 48 | 72.9 |
| 7 M | - | - | - | - | 1 | - | 29 | - | 8 | 1 | 1 | 3 | 5 | - | - | - | - | - | - | 48 | 60.4 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | 2 | - | 2 | 1 | - | - | 8 | - | 23 | 2 | 2 | - | 6 | - | - | - | - | - | 2 | 48 | 47.9 |
| 10 L | - | - | 1 | - | - | - | - | - | 4 | 24 | 7 | 4 | 6 | 2 | - | - | - | - | - | 48 | 50.0 |
| 11 R | - | - | - | - | - | 5 | - | - | - | 3 | 25 | 2 | 7 | 6 | - | - | - | - | - | 48 | 52.1 |
| 12 W | 1 | 1 | 1 | 3 | - | 1 | - | - | 2 | - | 1 | 15 | 10 | 9 | 4 | - | - | - | - | 48 | 31.3 |
| 13 J | - | - | - | - | - | - | 1 | - | - | - | - | - | 46 | - | - | 1 | - | - | - | 48 | 95.8 |
| 14 H | - | - | - | 2 | - | - | 2 | - | 2 | - | - | - | 3 | 36 | - | 3 | - | - | - | 48 | 75.0 |
| 15 B | 4 | - | 3 | 3 | - | - | 4 | - | - | - | - | 10 | 1 | 4 | 13 | 5 | 1 | - | - | 48 | 27.1 |
| 16 D | 2 | 3 | - | 1 | - | - | 1 | - | - | - | - | 1 | 3 | - | 3 | 34 | - | - | - | 48 | 70.8 |
| 17 V | 2 | 1 | 3 | 10 | 2 | 7 | - | - | - | - | - | 9 | - | 4 | - | 3 | 4 | 3 | - | 48 | 8.3 |
| 18 Z | - | - | - | - | 32 | - | 1 | - | - | - | - | - | 3 | 3 | - | - | - | 7 | 2 | 48 | 14.6 |
| Confusion | 20 | 9 | 20 | 36 | 37 | 32 | 17 | 0 | 17 | 8 | 14 | 36 | 56 | 41 | 12 | 20 | 29 | 8 | 6 | 418 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 45 | - | - | - | - | 1 | - | - | - | - | - | - | - | 2 | - | - | 48 | 93.8 |
| 2 AU | - | 37 | 11 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 77.1 |
| 3 A | - | 1 | 94 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 96 | 97.9 |
| 4 EE | - | - | - | 26 | 6 | - | 3 | - | 10 | - | - | - | 1 | - | - | 2 | 48 | 54.2 |
| 5 IJ | - | - | - | 1 | 44 | - | 3 | - | - | - | - | - | - | - | - | - | 48 | 91.7 |
| 6 EU | - | - | - | - | - | 41 | - | - | 2 | - | - | - | 1 | - | 4 | - | 48 | 85.4 |
| 7 E | 1 | - | 2 | 3 | 1 | - | 81 | - | - | 3 | - | - | - | - | 4 | 1 | 96 | 84.4 |
| 8 IE | - | - | - | - | - | - | - | 43 | 2 | - | - | 1 | 1 | - | - | 1 | 48 | 89.6 |
| 9 I | - | - | - | 2 | - | - | 1 | 11 | 32 | - | - | - | 2 | - | - | - | 48 | 66.7 |
| 10 OO | - | 6 | 5 | - | - | - | - | - | 1 | 19 | - | 16 | - | - | - | 1 | 48 | 39.6 |
| 11 OE | - | - | - | - | - | 1 | - | 6 | - | - | 34 | 4 | 2 | - | - | 1 | 48 | 70.8 |
| 12 O | - | - | 4 | - | - | - | - | - | - | 2 | 2 | 40 | - | - | - | - | 48 | 83.3 |
| 13 UU | - | - | - | - | - | - | - | 5 | 2 | - | 4 | - | 36 | - | 1 | - | 48 | 75.0 |
| 14 UI | - | - | - | - | - | 2 | - | - | - | - | - | - | - | 46 | - | - | 48 | 95.8 |
| 15 U | - | - | 1 | - | - | 4 | - | - | - | - | 1 | - | 6 | 1 | 35 | - | 48 | 72.9 |
| Confusion | 1 | 7 | 23 | 6 | 7 | 8 | 7 | 22 | 20 | 2 | 7 | 21 | 13 | 4 | 9 | 6 | 163 | |

Table A.5 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for aircraft noise at 6 dB SNR, MALE speech.

| Response / Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 40 | 1 | 3 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 83.3 |
| 2 T | - | 47 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 97.9 |
| 3 K | - | 1 | 40 | - | - | 4 | - | - | - | - | - | - | - | 3 | - | - | - | - | - | 48 | 83.3 |
| 4 F | - | - | - | 31 | - | 5 | - | - | - | - | - | - | - | - | - | - | 12 | - | - | 48 | 64.6 |
| 5 S | - | - | 1 | - | 44 | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | 48 | 91.7 |
| 6 G | 2 | - | 1 | 2 | - | 41 | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | 48 | 85.4 |
| 7 M | - | - | - | - | - | - | 46 | - | 2 | - | - | - | - | - | - | - | - | - | - | 48 | 95.8 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 3 | - | 45 | - | - | - | - | - | - | - | - | - | - | 48 | 93.8 |
| 10 L | - | - | - | - | - | - | 2 | - | 2 | 40 | - | - | 3 | - | - | 1 | - | - | - | 48 | 83.3 |
| 11 R | - | - | - | - | - | - | 2 | - | - | 1 | 38 | - | 2 | - | 5 | - | - | - | - | 48 | 79.2 |
| 12 W | 1 | - | - | 1 | - | - | 1 | - | - | - | 1 | 37 | 1 | - | 6 | - | - | - | - | 48 | 77.1 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | - | 47 | - | - | 1 | - | - | - | 48 | 97.9 |
| 14 H | - | - | - | - | - | - | - | - | - | - | 1 | - | 10 | 37 | - | - | - | - | - | 48 | 77.1 |
| 15 B | 5 | - | - | - | - | - | - | - | - | - | - | 5 | - | - | 38 | - | - | - | - | 48 | 79.2 |
| 16 D | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 47 | - | - | - | 48 | 97.9 |
| 17 V | 1 | - | - | 18 | - | 12 | - | - | - | - | 1 | 2 | - | - | - | - | 14 | - | - | 48 | 29.2 |
| 18 Z | - | - | - | - | 34 | - | - | - | - | - | - | - | - | - | - | - | - | 14 | - | 48 | 29.2 |
| Confusion | 9 | 3 | 5 | 26 | 34 | 21 | 8 | 0 | 4 | 1 | 3 | 7 | 16 | 4 | 11 | 2 | 13 | 3 | 0 | 170 | |

| Response / Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 46 | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 48 | 95.8 |
| 2 AU | - | 46 | 1 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 48 | 95.8 |
| 3 A | - | 3 | 88 | - | - | - | - | - | - | - | - | 3 | - | - | 2 | - | 96 | 91.7 |
| 4 EE | - | - | - | 43 | - | - | 3 | 1 | 1 | - | - | - | - | - | - | - | 48 | 89.6 |
| 5 IJ | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 6 EU | - | - | - | - | - | 44 | - | - | - | - | - | - | - | - | 4 | - | 48 | 91.7 |
| 7 E | - | - | 1 | - | 2 | - | 86 | - | 3 | - | - | - | - | - | - | - | 92 | 93.5 |
| 8 IE | - | - | - | - | - | - | - | 45 | 2 | - | - | 1 | - | - | - | - | 48 | 93.8 |
| 9 I | - | - | - | - | - | - | 1 | - | 51 | - | - | - | - | - | - | - | 52 | 98.1 |
| 10 OO | - | 6 | 1 | - | - | - | - | - | - | 37 | - | 4 | - | - | - | - | 48 | 77.1 |
| 11 OE | - | - | - | - | - | - | - | - | - | 1 | 47 | - | - | - | - | - | 48 | 97.9 |
| 12 O | - | - | - | - | - | - | - | - | - | 5 | - | 43 | - | - | - | - | 48 | 89.6 |
| 13 UU | - | - | - | - | - | 1 | - | - | - | - | 10 | - | 34 | - | 3 | - | 48 | 70.8 |
| 14 UI | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | 48 | 100.0 |
| 15 U | - | - | - | - | - | 3 | - | - | - | - | 1 | 6 | - | - | 38 | - | 48 | 79.2 |
| Confusion | 0 | 9 | 4 | 0 | 2 | 4 | 4 | 1 | 6 | 7 | 11 | 13 | 1 | 1 | 9 | 0 | 72 | |

Table A.6 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for aircraft noise at 12 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 46 | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 95.8 |
| 2 T | - | 44 | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 1 | 48 | 91.7 |
| 3 K | 2 | - | 46 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 95.8 |
| 4 F | - | - | - | 27 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | 19 | - | - | 48 | 56.3 |
| 5 S | - | - | - | - | 44 | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | 48 | 91.7 |
| 6 G | - | - | - | 1 | - | 47 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 97.9 |
| 7 M | - | - | - | - | - | - | 44 | - | 3 | 1 | - | - | - | - | - | - | - | - | - | 48 | 91.7 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | - | - | 45 | 1 | - | - | - | - | - | - | - | - | 2 | 48 | 93.8 |
| 10 L | - | - | - | - | - | - | - | - | 3 | 45 | - | - | - | - | - | - | - | - | - | 48 | 93.8 |
| 11 R | - | - | - | - | - | - | - | - | - | - | 47 | - | - | - | 1 | - | - | - | - | 48 | 97.9 |
| 12 W | - | - | - | 2 | - | - | - | - | - | - | - | 42 | - | 1 | 1 | - | 2 | - | - | 48 | 87.5 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | - | 47 | - | - | - | - | - | 1 | 48 | 97.9 |
| 14 H | - | - | - | - | - | - | - | - | - | - | - | 4 | 1 | 43 | - | - | - | - | - | 48 | 89.6 |
| 15 B | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 45 | 2 | - | - | - | 48 | 93.8 |
| 16 D | - | 4 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 42 | - | - | 1 | 48 | 87.5 |
| 17 V | - | - | - | 19 | - | 2 | - | - | - | - | - | 7 | - | 2 | - | - | 18 | - | - | 48 | 37.5 |
| 18 Z | - | - | - | - | 33 | - | - | - | - | - | - | - | - | - | - | - | - | 15 | - | 48 | 31.3 |
| Confusion | 2 | 5 | 0 | 23 | 34 | 3 | 0 | 0 | 6 | 2 | 0 | 13 | 1 | 3 | 2 | 5 | 21 | 4 | 5 | 129 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 2 AU | - | 37 | 11 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 77.1 |
| 3 A | - | - | 96 | - | - | - | - | - | - | - | - | - | - | - | - | - | 96 | 100.0 |
| 4 EE | - | - | - | 43 | - | - | - | - | 5 | - | - | - | - | - | - | - | 48 | 89.6 |
| 5 IJ | - | - | - | - | 43 | - | - | - | - | - | - | - | - | 5 | - | - | 48 | 89.6 |
| 6 EU | - | - | - | - | - | 39 | - | - | - | - | - | - | - | - | 9 | - | 48 | 81.3 |
| 7 E | - | - | - | - | - | - | 92 | 1 | 2 | - | - | - | - | - | - | 1 | 96 | 95.8 |
| 8 IE | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 9 I | - | - | - | 2 | - | - | 3 | 1 | 42 | - | - | - | - | - | - | - | 48 | 87.5 |
| 10 OO | - | 1 | - | - | - | - | - | - | - | 41 | - | 5 | - | - | - | 1 | 48 | 85.4 |
| 11 OE | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | 48 | 100.0 |
| 12 O | - | - | - | - | - | - | - | - | - | - | - | 47 | - | - | - | 1 | 48 | 97.9 |
| 13 UU | - | - | - | - | - | - | - | - | - | - | - | - | 46 | - | - | 2 | 48 | 95.8 |
| 14 UI | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | 48 | 100.0 |
| 15 U | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 47 | - | 48 | 97.9 |
| Confusion | 0 | 1 | 11 | 2 | 0 | 1 | 3 | 2 | 7 | 0 | 0 | 5 | 0 | 5 | 9 | 5 | 51 | |

Table A.7 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for vehicle noise at 6 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 34 | – | 3 | 2 | – | – | – | – | – | – | – | 2 | – | 4 | 3 | – | – | – | – | 48 | 70.8 |
| 2 T | – | 39 | – | – | – | – | – | – | – | – | – | – | – | – | – | 9 | – | – | – | 48 | 81.3 |
| 3 K | – | – | 45 | 1 | – | 1 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | 48 | 93.8 |
| 4 F | – | – | – | 29 | – | – | – | – | – | – | – | 1 | – | – | – | – | 18 | – | – | 48 | 60.4 |
| 5 S | – | – | – | – | 37 | – | – | – | – | – | – | – | – | – | – | – | – | 11 | – | 48 | 77.1 |
| 6 G | 1 | 1 | – | – | – | 46 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 95.8 |
| 7 M | – | – | – | 1 | – | – | 33 | – | 4 | – | – | 7 | – | 2 | 1 | – | – | – | – | 48 | 68.8 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | 1 | – | – | – | – | 47 | – | – | – | – | – | – | – | – | – | – | 48 | 97.9 |
| 10 L | – | – | – | – | – | – | – | – | 4 | 44 | – | – | – | – | – | – | – | – | – | 48 | 91.7 |
| 11 R | – | – | 2 | – | 2 | – | – | – | – | – | 42 | – | – | 1 | – | 1 | – | – | – | 48 | 87.5 |
| 12 W | – | – | – | 2 | – | – | – | – | – | – | – | 39 | 1 | 2 | 2 | – | 2 | – | – | 48 | 81.3 |
| 13 J | – | – | – | – | – | – | – | – | – | – | – | – | 48 | – | – | – | – | – | – | 48 | 100.0 |
| 14 H | – | – | – | 2 | – | – | – | – | – | – | 3 | 5 | 1 | 37 | – | – | – | – | – | 48 | 77.1 |
| 15 B | 9 | 1 | – | 3 | – | – | – | – | – | – | – | 4 | – | – | 28 | 3 | – | – | – | 48 | 58.3 |
| 16 D | – | 10 | – | – | – | – | – | – | – | – | – | – | – | – | – | 38 | – | – | – | 48 | 79.2 |
| 17 V | – | – | – | 22 | – | 1 | – | – | – | – | – | – | – | 1 | – | – | 24 | – | – | 48 | 50.0 |
| 18 Z | – | – | – | – | 32 | – | – | – | – | – | – | – | – | – | – | – | – | 16 | – | 48 | 33.3 |
| Confusion | 10 | 12 | 5 | 34 | 34 | 2 | 0 | 0 | 8 | 0 | 3 | 19 | 2 | 11 | 6 | 13 | 20 | 11 | 0 | 190 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 47 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 97.9 |
| 2 AU | – | 37 | 11 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 77.1 |
| 3 A | – | – | 94 | – | – | – | – | – | – | – | – | 2 | – | – | – | – | 96 | 97.9 |
| 4 EE | – | – | – | 42 | – | – | – | – | 6 | – | – | – | – | – | – | – | 48 | 87.5 |
| 5 IJ | – | – | – | 1 | 46 | – | 1 | – | – | – | – | – | – | – | – | – | 48 | 95.8 |
| 6 EU | – | – | – | – | – | 38 | – | – | – | – | – | – | – | 10 | – | – | 48 | 79.2 |
| 7 E | – | – | – | – | 2 | 1 | 79 | 1 | 2 | – | – | – | – | 8 | 2 | 1 | 96 | 82.3 |
| 8 IE | – | – | – | 2 | – | – | 1 | 44 | 1 | – | – | – | – | – | – | – | 48 | 91.7 |
| 9 I | – | – | – | 1 | – | – | – | – | 47 | – | – | – | – | – | – | – | 48 | 97.9 |
| 10 OO | – | – | – | – | – | – | – | – | – | 44 | – | 4 | – | – | – | – | 48 | 91.7 |
| 11 OE | – | – | – | – | – | 1 | – | – | – | – | 47 | – | – | – | – | – | 48 | 97.9 |
| 12 O | – | – | 2 | – | – | – | – | – | – | 1 | – | 45 | – | – | – | – | 48 | 93.8 |
| 13 UU | – | – | – | – | – | – | – | – | – | – | 9 | – | 42 | – | 1 | – | 52 | 80.8 |
| 14 UI | – | – | – | – | 1 | – | – | – | – | – | – | – | – | 47 | – | – | 48 | 97.9 |
| 15 U | – | – | – | – | – | 2 | – | – | – | – | – | – | – | – | 42 | – | 44 | 95.5 |
| Confusion | 0 | 0 | 14 | 4 | 3 | 4 | 2 | 1 | 9 | 1 | 9 | 6 | 0 | 8 | 13 | 1 | 75 | |

Table A.8 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for vehicle noise at 12 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 43 | - | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | - | - | - | 48 | 89.6 |
| 2 T | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 3 K | - | - | 44 | - | - | - | - | - | - | - | 1 | - | - | 3 | - | - | - | - | - | 48 | 91.7 |
| 4 F | - | - | - | 26 | - | 2 | - | - | - | - | - | - | - | - | - | - | 20 | - | - | 48 | 54.2 |
| 5 S | - | - | - | - | 43 | - | - | - | - | - | - | - | - | - | - | - | - | 5 | - | 48 | 89.6 |
| 6 G | - | - | - | - | - | 47 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 48 | 97.9 |
| 7 M | - | - | - | - | - | - | 43 | - | 5 | - | - | - | - | - | - | - | - | - | - | 48 | 89.6 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | - | - | 45 | - | - | 3 | - | - | - | - | - | - | - | 48 | 93.8 |
| 10 L | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 11 R | - | - | - | - | - | - | - | - | - | - | 44 | 1 | - | 3 | - | - | - | - | - | 48 | 91.7 |
| 12 W | - | - | - | - | - | - | - | - | - | - | 3 | 39 | 1 | - | 4 | 1 | - | - | - | 48 | 81.3 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | 48 | 100.0 |
| 14 H | - | - | - | - | - | 3 | - | - | - | - | - | 1 | - | 43 | 1 | - | - | - | - | 48 | 89.6 |
| 15 B | 5 | - | 1 | 1 | - | - | - | - | - | - | - | - | - | 1 | 40 | - | - | - | - | 48 | 83.3 |
| 16 D | - | 6 | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | 40 | - | - | - | 48 | 83.3 |
| 17 V | - | - | - | 23 | - | 1 | - | - | - | - | - | 4 | - | 1 | - | - | 19 | - | - | 48 | 39.6 |
| 18 Z | - | - | - | - | 28 | - | - | - | - | - | - | - | - | - | - | - | - | 20 | - | 48 | 41.7 |
| Confusion | 5 | 6 | 1 | 24 | 28 | 6 | 0 | 0 | 5 | 0 | 4 | 10 | 2 | 8 | 10 | 1 | 21 | 5 | 0 | 136 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 2 AU | - | 41 | 7 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 85.4 |
| 3 A | - | - | 96 | - | - | - | - | - | - | - | - | - | - | - | - | - | 96 | 100.0 |
| 4 EE | - | - | - | 44 | - | - | - | - | 4 | - | - | - | - | - | - | - | 48 | 91.7 |
| 5 IJ | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 6 EU | - | - | - | - | - | 34 | - | - | - | - | - | - | - | 1 | 13 | - | 48 | 70.8 |
| 7 E | - | - | - | - | 1 | - | 93 | - | - | - | - | - | - | 2 | - | - | 96 | 96.9 |
| 8 IE | - | - | - | - | - | - | - | 47 | 1 | - | - | - | - | - | - | - | 48 | 97.9 |
| 9 I | - | - | - | 1 | - | - | 6 | - | 41 | - | - | - | - | - | - | - | 48 | 85.4 |
| 10 OO | - | - | - | - | - | - | - | - | - | 46 | - | 2 | - | - | - | - | 48 | 95.8 |
| 11 OE | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | 48 | 100.0 |
| 12 O | - | - | 4 | - | - | - | 1 | - | - | - | - | 43 | - | - | - | - | 48 | 89.6 |
| 13 UU | - | - | - | - | - | - | - | - | - | - | - | - | 43 | 4 | 1 | - | 48 | 89.6 |
| 14 UI | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | 48 | 100.0 |
| 15 U | - | - | - | - | - | 3 | - | - | - | - | - | - | 4 | - | 41 | - | 48 | 85.4 |
| Confusion | 0 | 0 | 11 | 1 | 1 | 3 | 7 | 0 | 5 | 0 | 0 | 2 | 4 | 7 | 14 | 0 | 55 | |

Table A.9 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for aircraft noise at 6 dB SNR, MALE speech.

| Response<br>Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 23 | 1 | – | 6 | – | 2 | – | – | – | – | – | 2 | 3 | 8 | – | – | 3 | – | – | 48 | 47.9 |
| 2 T | 6 | 34 | 2 | – | 1 | – | – | – | – | – | – | – | 1 | – | 1 | 3 | – | – | – | 48 | 70.8 |
| 3 K | 2 | 1 | 31 | – | – | 6 | – | – | – | 1 | – | – | 2 | 5 | – | – | – | – | – | 48 | 64.6 |
| 4 F | 4 | – | – | 13 | 3 | 7 | – | – | – | – | – | – | 2 | 2 | – | – | 16 | 1 | – | 48 | 27.1 |
| 5 S | – | – | – | – | 40 | – | – | – | – | – | – | – | – | – | – | – | – | 8 | – | 48 | 83.3 |
| 6 G | 1 | 2 | – | 5 | 2 | 30 | – | – | – | – | – | – | 1 | 2 | – | – | 5 | – | – | 48 | 62.5 |
| 7 M | – | – | – | 1 | – | – | 15 | – | 12 | 5 | – | 2 | 12 | – | – | – | – | – | 1 | 48 | 31.3 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | – | – | – | 12 | – | 24 | 2 | – | – | 8 | 1 | – | – | – | – | 1 | 48 | 50.0 |
| 10 L | – | – | – | 1 | – | – | – | – | 2 | 20 | 9 | 1 | 14 | – | – | – | – | – | 1 | 48 | 41.7 |
| 11 R | 2 | – | – | – | – | 2 | – | – | – | 5 | 29 | 2 | 3 | 4 | 1 | – | – | – | – | 48 | 60.4 |
| 12 W | – | – | – | 2 | – | 1 | – | – | – | 1 | – | 24 | 11 | – | 5 | 3 | 1 | – | – | 48 | 50.0 |
| 13 J | – | – | 1 | – | – | – | – | – | – | 5 | 3 | 4 | 34 | – | – | 1 | – | – | – | 48 | 70.8 |
| 14 H | – | 1 | – | – | – | 5 | – | – | 1 | 1 | 2 | 3 | 11 | 20 | 1 | 3 | – | – | – | 48 | 41.7 |
| 15 B | 5 | – | – | 1 | – | – | 3 | – | 1 | – | – | 11 | 4 | 2 | 18 | 2 | 1 | – | – | 48 | 37.5 |
| 16 D | – | 1 | – | – | – | – | – | – | – | 1 | – | 4 | 12 | – | 3 | 27 | – | – | – | 48 | 56.3 |
| 17 V | 4 | – | 1 | 8 | – | 8 | – | – | – | – | 2 | 3 | 4 | 5 | 1 | 1 | 11 | – | – | 48 | 22.9 |
| 18 Z | – | – | – | – | 31 | – | – | – | 4 | – | 1 | – | 5 | – | – | – | – | 7 | – | 48 | 14.6 |
| Confusion | 24 | 6 | 4 | 24 | 37 | 31 | 15 | 0 | 20 | 21 | 17 | 32 | 93 | 29 | 12 | 13 | 26 | 9 | 3 | 416 | |

| Response<br>Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 45 | 2 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 93.8 |
| 2 AU | 2 | 33 | 12 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 48 | 68.8 |
| 3 A | – | – | 92 | – | – | – | 1 | – | – | – | – | – | – | 2 | – | 1 | 96 | 95.8 |
| 4 EE | – | – | – | 31 | 3 | – | – | 2 | 11 | – | – | – | 1 | – | – | – | 48 | 64.6 |
| 5 IJ | – | – | – | 6 | 41 | – | – | – | 1 | – | – | – | – | – | – | – | 48 | 85.4 |
| 6 EU | – | – | – | 1 | – | 37 | 2 | – | – | – | – | 2 | – | 2 | 4 | – | 48 | 77.1 |
| 7 E | – | – | 1 | 11 | 4 | 1 | 58 | – | 14 | – | 1 | – | – | 1 | 4 | 1 | 96 | 60.4 |
| 8 IE | – | – | – | – | – | – | – | 37 | 3 | – | 2 | – | 6 | – | – | – | 48 | 77.1 |
| 9 I | – | – | – | – | – | – | 3 | 9 | 31 | – | – | – | – | 5 | – | – | 48 | 64.6 |
| 10 OO | – | 4 | 5 | – | – | – | – | – | – | 31 | – | 8 | – | – | – | – | 48 | 64.6 |
| 11 OE | – | – | – | 1 | – | 1 | – | 5 | 3 | 6 | 21 | 3 | 4 | – | 3 | 1 | 48 | 43.8 |
| 12 O | – | – | 1 | – | – | – | – | – | – | 1 | – | 46 | – | – | – | – | 48 | 95.8 |
| 13 UU | – | – | – | 1 | – | – | – | 6 | 1 | 1 | 6 | – | 29 | – | 4 | – | 48 | 60.4 |
| 14 UI | 1 | – | – | – | – | 3 | – | – | – | – | – | – | 1 | 41 | 1 | 1 | 48 | 85.4 |
| 15 U | – | – | – | 1 | – | 3 | – | 2 | 11 | – | 1 | 2 | – | – | 28 | – | 48 | 58.3 |
| Confusion | 3 | 6 | 20 | 21 | 7 | 8 | 6 | 24 | 44 | 8 | 10 | 15 | 12 | 6 | 21 | 4 | 215 | |

Table A.10 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for aircraft noise at 12 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 32 | 2 | - | 3 | - | 4 | - | - | - | - | - | 1 | 1 | 1 | 2 | 2 | - | - | - | 48 | 66.7 |
| 2 T | 5 | 33 | 2 | 1 | - | 2 | - | - | - | - | - | - | - | 2 | - | 3 | - | - | - | 48 | 68.8 |
| 3 K | 7 | 1 | 33 | 2 | - | 2 | - | - | - | - | - | - | 1 | - | - | - | 2 | - | - | 48 | 68.8 |
| 4 F | - | - | 1 | 22 | - | 10 | - | - | - | - | - | - | - | - | - | - | 15 | - | - | 48 | 45.8 |
| 5 S | - | - | - | - | 43 | - | - | - | - | - | - | - | - | - | - | - | 1 | 4 | - | 48 | 89.6 |
| 6 G | - | - | - | 2 | - | 45 | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 48 | 93.8 |
| 7 M | - | - | - | - | - | - | 26 | - | 12 | 4 | - | - | 6 | - | - | - | - | - | - | 48 | 54.2 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 2 | - | 31 | 2 | - | 3 | 10 | - | - | - | - | - | - | 48 | 64.6 |
| 10 L | - | - | - | - | - | - | 1 | - | 2 | 32 | - | 1 | 12 | - | - | - | - | - | - | 48 | 66.7 |
| 11 R | - | - | - | - | - | - | - | - | - | - | 35 | 3 | 3 | 7 | - | - | - | - | - | 48 | 72.9 |
| 12 W | - | - | - | - | - | - | 1 | - | - | 1 | 2 | 41 | - | - | 1 | - | - | - | - | 48 | 85.4 |
| 13 J | - | - | - | - | - | - | - | - | 1 | 2 | 1 | 4 | 39 | - | - | 1 | - | - | - | 48 | 81.3 |
| 14 H | 1 | - | 2 | - | - | 2 | - | - | 1 | 2 | 5 | 2 | 4 | 27 | - | 2 | - | - | - | 48 | 56.3 |
| 15 B | - | - | - | - | - | - | - | - | - | - | - | 15 | 6 | - | 23 | 4 | - | - | - | 48 | 47.9 |
| 16 D | - | - | - | 1 | - | 1 | - | - | - | - | - | 1 | 8 | - | 1 | 36 | - | - | - | 48 | 75.0 |
| 17 V | 1 | 1 | 1 | 13 | 1 | 2 | - | - | - | - | - | 11 | 2 | 5 | 1 | 1 | 9 | - | - | 48 | 18.8 |
| 18 Z | - | - | - | - | 31 | - | - | - | - | - | - | 1 | 5 | - | 1 | - | - | 10 | - | 48 | 20.8 |
| Confusion | 14 | 4 | 6 | 22 | 32 | 23 | 4 | 0 | 16 | 11 | 9 | 42 | 60 | 15 | 5 | 14 | 18 | 4 | 0 | 299 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 41 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | 44 | 93.2 |
| 2 AU | 1 | 35 | 11 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 48 | 72.9 |
| 3 A | - | - | 96 | - | - | 1 | - | - | - | 1 | - | 2 | - | - | - | - | 100 | 96.0 |
| 4 EE | - | - | - | 44 | - | - | - | - | 4 | - | - | - | - | - | - | - | 48 | 91.7 |
| 5 IJ | - | - | - | 9 | 39 | - | - | - | - | - | - | - | - | - | - | - | 48 | 81.3 |
| 6 EU | - | - | 1 | - | 1 | 23 | - | - | 3 | - | - | 1 | 3 | 2 | 14 | - | 48 | 47.9 |
| 7 E | - | - | 2 | 7 | - | - | 54 | 2 | 18 | - | - | - | 1 | 2 | 10 | - | 96 | 56.3 |
| 8 IE | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 9 I | - | - | - | - | - | - | - | 1 | 11 | 36 | - | - | - | - | - | - | 48 | 75.0 |
| 10 OO | - | - | 1 | - | - | - | - | - | - | 30 | - | 14 | - | - | 3 | - | 48 | 62.5 |
| 11 OE | - | - | - | - | - | - | - | 2 | 2 | 2 | 33 | 3 | 6 | - | - | - | 48 | 68.8 |
| 12 O | - | - | 3 | - | - | - | - | - | - | 2 | 2 | 41 | - | - | - | - | 48 | 85.4 |
| 13 UU | - | - | - | - | - | - | - | 11 | 4 | - | 1 | - | 32 | - | - | - | 48 | 66.7 |
| 14 UI | - | - | - | - | - | 3 | 1 | - | - | - | - | - | - | 44 | - | - | 48 | 91.7 |
| 15 U | - | - | - | - | 1 | 3 | 3 | 2 | 7 | - | - | - | 2 | - | 30 | - | 48 | 62.5 |
| Confusion | 1 | 1 | 20 | 16 | 2 | 7 | 5 | 28 | 38 | 6 | 3 | 20 | 12 | 4 | 27 | 0 | 190 | |

Table A.11 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for vehicle noise at 6 dB SNR, MALE speech.

```
Response  P  T  K  F  S  G  M NG  N  L  R  W  J  H  B  D  V  Z ??  Tot    %
Stimulus
 1   P   25  -  4  5  -  2  -  -  -  -  -  5  1  4  1  1  -  -  -   48  52.1
 2   T    2 28  -  1  -  -  -  -  -  -  1  1  4  2  5  2  2  -  -   48  58.3
 3   K    1  2 25  1  -  5  -  -  1  -  4  -  5  -  -  4  -  -  -   48  52.1
 4   F    -  -  1 19  1  6  -  -  -  -  -  3  2  1  1  - 14  -  -   48  39.6
 5   S    -  -  -  - 43  -  -  -  -  -  -  -  -  -  -  -  -  5  -   48  89.6
 6   G    -  1  -  1  - 36  -  -  -  -  2  1  -  2  3  -  2  -  -   48  75.0
 7   M    -  -  1  3  -  1 21  -  5  1  -  8  7  -  1  -  -  -  -   48  43.8
 8  NG    -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -    0  --.-
 9   N    -  -  -  -  -  -  3  - 26  4  -  - 10  1  1  3  -  -  -   48  54.2
10   L    -  -  -  -  1  -  5  -  3 26  -  - 10  1  -  -  1  -  1   48  54.2
11   R    -  -  1  -  -  -  -  -  -  1 36  2  3  5  -  -  -  -  -   48  75.0
12   W    -  -  -  6  1  1  2  -  -  -  4 14  3  7  8  1  1  -  -   48  29.2
13   J    -  -  -  -  -  -  -  -  -  -  1  - 44  2  1  -  -  -  -   48  91.7
14   H    -  -  -  -  -  1  -  -  -  2  1  6  4 32  1  -  1  -  -   48  66.7
15   B   12  -  -  6  -  1  -  -  -  -  -  8  -  3 16  -  2  -  -   48  33.3
16   D    2  4  4  4  -  2  -  -  -  -  -  -  6  5  - 21  -  -  -   48  43.8
17   V    -  -  - 15  -  7  -  -  -  -  -  1  2  3  -  1 19  -  -   48  39.6
18   Z    -  -  -  - 41  -  -  -  -  -  -  -  -  -  -  -  -  7  -   48  14.6
Confusion 17  7 11 42 44 26 10  0  9  8 13 35 57 36 22 12 23  5  1 378
```

```
Response AA AU  A EE IJ EU  E IE  I OO OE  O UU UI  U ??  Tot    %
Stimulus
 1  AA   46  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -   48  95.8
 2  AU    - 33 12  -  -  -  3  -  -  -  -  -  -  -  -  -   48  68.8
 3   A    -  1 93  -  -  -  -  -  -  1  -  1  -  -  -  -   96  96.9
 4  EE    -  -  - 39  -  -  3  -  6  -  -  -  -  -  -  -   48  81.3
 5  IJ    -  -  -  6 36  -  5  -  -  -  -  -  -  1  -  -   48  75.0
 6  EU    -  -  -  2  - 36  -  -  2  -  -  -  3  -  5  -   48  75.0
 7   E    -  -  -  7  1  1 52  4 22  -  -  -  -  4  5  -   96  54.2
 8  IE    -  -  -  -  -  -  - 38  5  -  -  -  5  -  -  -   48  79.2
 9   I    -  -  -  6  -  -  - 18 24  -  -  -  -  -  -  -   48  50.0
10  OO    -  -  4  -  -  -  -  -  - 29  3 11  -  -  1  -   48  60.4
11  OE    -  -  -  -  -  -  -  -  2  1 36  3  6  -  -  -   48  75.0
12   O    -  -  1  -  -  -  1  -  -  1  1 43  -  -  -  1   48  89.6
13  UU    -  -  -  -  -  -  -  4  4  -  2  - 33  -  1  -   44  75.0
14  UI    -  -  -  -  - 11  1  -  -  -  -  -  - 38  2  -   52  73.1
15   U    -  -  -  -  -  2  1  -  5  -  1  -  1  1 37  -   48  77.1
Confusion  0  3 17 21  1 14 14 26 46  3  7 15 15  6 14  1 203
```

Table A.12 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for vehicle noise at 12 dB SNR, MALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 29 | 1 | 2 | 2 | – | 2 | – | – | – | – | – | – | 1 | 6 | 3 | 2 | – | – | – | 48 | 60.4 |
| 2 T | 8 | 28 | 6 | – | – | – | – | – | – | – | – | – | 3 | 2 | 1 | – | – | – | – | 48 | 58.3 |
| 3 K | – | 1 | 46 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 95.8 |
| 4 F | 1 | 2 | – | 15 | 1 | 9 | – | – | – | – | – | – | 1 | 4 | – | – | 15 | – | – | 48 | 31.3 |
| 5 S | – | – | – | – | 36 | – | – | – | – | – | – | – | – | – | – | – | – | 12 | – | 48 | 75.0 |
| 6 G | 1 | – | – | 1 | – | 45 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 48 | 93.8 |
| 7 M | – | – | – | – | – | – | 16 | – | 17 | 1 | – | 4 | 9 | – | – | – | – | – | 1 | 48 | 33.3 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | – | – | – | 2 | – | 25 | 1 | – | – | 16 | – | – | – | – | – | – | 44 | 56.8 |
| 10 L | – | – | – | – | – | 1 | – | – | 8 | 26 | 1 | 2 | 8 | 1 | 1 | – | – | – | – | 48 | 54.2 |
| 11 R | – | – | – | – | – | 4 | – | – | – | – | 40 | – | 1 | 2 | 1 | – | – | – | – | 48 | 83.3 |
| 12 W | – | – | – | – | – | – | – | – | – | – | 1 | 39 | 5 | – | 3 | – | – | – | – | 48 | 81.3 |
| 13 J | – | 1 | – | – | – | – | 1 | – | – | – | – | 1 | 37 | 6 | – | – | – | – | 2 | 48 | 77.1 |
| 14 H | 1 | – | – | – | 1 | 4 | – | – | – | – | 4 | 1 | 7 | 30 | – | – | – | – | – | 48 | 62.5 |
| 15 B | 5 | – | – | – | – | – | – | – | – | – | – | 13 | 2 | – | 27 | 1 | – | – | – | 48 | 56.3 |
| 16 D | 5 | 1 | 1 | – | – | – | – | – | 1 | – | – | 3 | 6 | 5 | 2 | 28 | – | – | – | 52 | 53.8 |
| 17 V | 3 | 1 | – | 15 | 1 | 2 | – | – | – | – | 2 | 3 | 5 | 2 | – | 1 | 13 | – | – | 48 | 27.1 |
| 18 Z | – | – | – | – | 24 | – | – | – | – | 1 | – | – | 8 | – | – | – | – | 15 | – | 48 | 31.3 |
| Confusion | 24 | 7 | 9 | 18 | 27 | 23 | 3 | 0 | 26 | 3 | 9 | 26 | 72 | 28 | 11 | 4 | 16 | 12 | 3 | 321 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 47 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 97.9 |
| 2 AU | 1 | 31 | 15 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 48 | 64.6 |
| 3 A | – | 1 | 91 | – | – | – | – | – | – | – | – | 4 | – | – | – | – | 96 | 94.8 |
| 4 EE | – | – | – | 37 | – | – | – | 3 | 8 | – | – | – | – | – | – | – | 48 | 77.1 |
| 5 IJ | – | – | – | 5 | 41 | – | – | 2 | – | – | – | – | – | – | – | – | 48 | 85.4 |
| 6 EU | – | – | – | – | – | 31 | – | – | – | – | – | – | 5 | – | 12 | – | 48 | 64.6 |
| 7 E | – | – | – | 1 | 5 | – | 67 | – | 18 | – | – | – | – | 1 | 4 | – | 96 | 69.8 |
| 8 IE | – | – | – | – | – | – | – | 38 | 6 | – | – | – | 3 | – | – | 1 | 48 | 79.2 |
| 9 I | – | – | – | 2 | – | – | 1 | – | 42 | – | – | – | – | 3 | – | – | 48 | 87.5 |
| 10 OO | – | 3 | 1 | – | – | – | – | – | – | 26 | – | 16 | – | – | 1 | 1 | 48 | 54.2 |
| 11 OE | – | – | – | – | – | – | – | – | 3 | – | 36 | 7 | 1 | – | 1 | – | 48 | 75.0 |
| 12 O | – | 1 | 1 | – | – | – | – | – | – | 3 | – | 42 | – | – | – | 1 | 48 | 87.5 |
| 13 UU | – | – | – | – | – | – | – | 7 | – | – | 2 | – | 39 | – | – | – | 48 | 81.3 |
| 14 UI | – | – | – | – | – | 4 | – | – | – | – | – | – | – | 44 | – | – | 48 | 91.7 |
| 15 U | – | – | – | – | – | 3 | – | 2 | 5 | – | – | – | 8 | – | 30 | – | 48 | 62.5 |
| Confusion | 1 | 5 | 18 | 8 | 5 | 7 | 1 | 14 | 40 | 4 | 2 | 27 | 17 | 1 | 21 | 3 | 174 | |

Table A.13 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for aircraft noise at 6 dB SNR, FEMALE speech.

```
Response   P   T   K   F   S   G   M NG   N   L   R   W   J   H   B   D   V   Z  ??  Tot    %
Stimulus
 1   P    17   7   7   3   -   3   1   -   -   2   -   -   2   1   -   -   3   2   -   48  35.4
 2   T     4  22  14   1   -   1   -   -   -   -   -   -   1   1   1   -   3   -   -   48  45.8
 3   K     1   1  34   -   2   2   1   -   1   -   -   -   1   2   -   -   3   -   -   48  70.8
 4   F     8   2  11  11   -   1   -   -   -   -   -   -   1   3   -   -   9   -   2   48  22.9
 5   S     2   1   1   -  33   4   -   -   -   -   -   -   1   -   -   -   -   6   -   48  68.8
 6   G     -   -   5   3   -  25   1   -   1   -   -   -   -   6   1   -   5   -   1   48  52.1
 7   M     -   -   -   -   -   -  13   -  14   3   -   -  13   3   -   -   -   1   1   48  27.1
 8  NG     -   -   -   -   -   -   -   -   -   -   -   -   -   -   -   -   -   -   -    0  --.-
 9   N     -   -   -   -   -   -   4   -  18   4   -   1  17   1   -   -   1   -   2   48  37.5
10   L     -   -   -   -   -   1   1   -   1  20   1   5  18   -   -   -   -   1   -   48  41.7
11   R     -   -   -   -   2   -   1   -   5   2  18   7   7   5   -   1   -   -   -   48  37.5
12   W     -   -   -   -   -   -   -   -   1   2   9  16  13   3   1   2   1   -   -   48  33.3
13   J     -   -   -   1   1   -   -   -   2   -   -   7  33   -   1   2   -   1   -   48  68.8
14   H     2   -   2   1   2   -   1   -   1   3   1   -  14  16   -   3   2   -   -   48  33.3
15   B     1   -   -   -   -   -   -   -   1   1   4  10   5   -  24   2   -   -   -   48  50.0
16   D     1   2   3   -   -   1   -   -   1   -   2   -  11   -   7  19   1   -   -   48  39.6
17   V     4   4   3   8   3   2   -   -   -   -   -   4   7   7   -   2   4   -   -   48   8.3
18   Z     1   -   -   -  21   1   -   -   -   1   -   -  12   2   -   -   -  10   -   48  20.8
Confusion 24  17  46  17  31  16  10   0  28  18  17  34 123  34  11  12  28  11   6  483
```

```
Response  AA  AU   A  EE  IJ  EU   E  IE   I  OO  OE   O  UU  UI   U  ??  Tot    %
Stimulus
 1  AA    36   -   3   -   -   1   -   1   1   2   -   1   -   2   -   1   48  75.0
 2  AU     1  21  13   -   -   -   2   -   -   3   -   3   -   5   -   -   48  43.8
 3   A    10   6  63   -   4   -   -   2   1   -   4   2   1   2   1   -   96  65.6
 4  EE     -   -   -  22   2   2   2   7  10   -   1   -   -   -   1   1   48  45.8
 5  IJ     -   1   -   1  35   -   1   -   1   2   -   1   -   5   1   -   48  72.9
 6  EU     -   -   -   4   1  22   -   -   1   -   4   1   8   4   3   -   48  45.8
 7   E     -   3   -   2   5   2  39   -   9   2   1   6   7   5   9   -   96  40.6
 8  IE     -   -   -   -   -   1   -   -  32   3   -   3   1   3   -   4   1   48  66.7
 9   I     -   -   -   3   1   -   1  19  15   -   2   1   5   -   1   -   48  31.3
10  OO     1   3   2   -   -   -   -   -   -  26   3   6   1   -   2   -   44  59.1
11  OE     -   -   -   -   -   2   -   7   2   3  18   2   9   -   3   2   48  37.5
12   O     -   2   5   1   -   -   -   -   -   6   1  36   1   -   -   -   52  69.2
13  UU     -   -   -   2   1   -   -  16   2   -   7   -  16   -   3   1   48  33.3
14  UI     4   2   6   -   2   -   1   -   -   2   -   3   -  28   -   -   48  58.3
15   U     -   -   -   -   -   6   -   3   7   -   3   3   4   -  22   -   48  45.8
Confusion 16  17  29  13  17  13   7  61  37  20  29  30  39  23  28   6  385
```

Table A.14  Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for aircraft noise at 12 dB SNR, FEMALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 13 | 8 | 7 | 10 | – | 3 | – | – | – | – | – | – | – | 3 | – | – | 3 | – | 1 | 48 | 27.1 |
| 2 T | 3 | 22 | 12 | 3 | – | 2 | – | – | – | – | – | – | 1 | 2 | – | – | 1 | 2 | – | 48 | 45.8 |
| 3 K | 3 | 1 | 40 | – | 1 | 2 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 48 | 83.3 |
| 4 F | 4 | 1 | 8 | 21 | 2 | 2 | – | – | – | – | – | – | 2 | – | – | – | 6 | 2 | – | 48 | 43.8 |
| 5 S | – | – | – | – | 41 | – | – | – | – | – | – | – | – | – | – | – | – | 7 | – | 48 | 85.4 |
| 6 G | – | – | 1 | 2 | – | 44 | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 48 | 91.7 |
| 7 M | – | – | – | – | – | – | 15 | – | 13 | – | – | 2 | 16 | 1 | – | – | – | – | 1 | 48 | 31.3 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | – | – | – | 6 | – | 26 | 2 | – | – | 14 | – | – | – | – | – | – | 48 | 54.2 |
| 10 L | – | – | – | – | 1 | – | 2 | – | 9 | 18 | – | – | 15 | 1 | – | 2 | – | – | – | 48 | 37.5 |
| 11 R | – | – | – | – | – | – | – | – | 2 | – | 39 | 2 | 5 | – | – | – | – | – | – | 48 | 81.3 |
| 12 W | – | – | – | 1 | – | – | 1 | – | – | 2 | 1 | 34 | 6 | – | 2 | – | – | 1 | – | 48 | 70.8 |
| 13 J | – | – | – | – | – | – | – | – | 1 | 1 | 2 | 3 | 40 | – | – | – | 1 | – | – | 48 | 83.3 |
| 14 H | 2 | – | 3 | – | – | 6 | – | – | – | 1 | 1 | 2 | 6 | 24 | 1 | – | 1 | – | 1 | 48 | 50.0 |
| 15 B | 4 | 1 | 1 | – | 2 | – | 1 | – | – | 2 | 1 | 13 | 5 | 1 | 16 | 1 | – | – | – | 48 | 33.3 |
| 16 D | 1 | 1 | 1 | – | 1 | – | – | – | – | – | 2 | 1 | 10 | 1 | 6 | 21 | – | 3 | – | 48 | 43.8 |
| 17 V | 3 | 1 | 1 | 18 | – | 6 | – | – | – | 1 | – | 5 | 1 | 3 | 1 | – | 7 | 1 | – | 48 | 14.6 |
| 18 Z | 1 | – | – | 1 | 23 | – | – | – | – | – | – | 1 | 6 | 2 | – | 1 | 1 | 12 | – | 48 | 25.0 |
| Confusion | 21 | 13 | 34 | 35 | 30 | 21 | 10 | 0 | 25 | 9 | 7 | 29 | 87 | 14 | 10 | 5 | 13 | 17 | 3 | 383 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 39 | 2 | 7 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 81.3 |
| 2 AU | 2 | 37 | 9 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 77.1 |
| 3 A | 4 | 1 | 77 | – | – | – | – | – | – | 2 | – | 8 | – | 3 | – | 1 | 96 | 80.2 |
| 4 EE | – | – | – | 35 | 2 | – | 1 | 2 | 7 | – | – | – | – | – | 1 | – | 48 | 72.9 |
| 5 IJ | – | – | – | 3 | 36 | – | 2 | – | 1 | – | – | – | – | 6 | – | – | 48 | 75.0 |
| 6 EU | – | – | – | 2 | – | 33 | 1 | – | 1 | 1 | 1 | – | 4 | 1 | 11 | 1 | 56 | 58.9 |
| 7 E | – | – | 4 | 2 | 6 | 4 | 53 | – | 11 | – | – | 4 | – | 3 | 9 | – | 96 | 55.2 |
| 8 IE | – | – | – | 1 | – | – | – | 30 | 8 | – | 1 | – | 4 | – | 4 | – | 48 | 62.5 |
| 9 I | – | – | – | 6 | – | – | 1 | 14 | 23 | – | – | – | 2 | – | 2 | – | 48 | 47.9 |
| 10 OO | – | – | – | 1 | – | 1 | – | – | – | 31 | 3 | 6 | 1 | 1 | 4 | – | 48 | 64.6 |
| 11 OE | – | 3 | – | – | 1 | – | – | 10 | 2 | 2 | 19 | 1 | 6 | 1 | 3 | – | 48 | 39.6 |
| 12 O | – | – | 2 | – | – | – | – | – | 1 | 1 | 7 | 34 | – | – | 3 | – | 48 | 70.8 |
| 13 UU | – | – | – | 2 | – | – | – | 13 | 2 | – | 3 | 1 | 25 | – | 6 | – | 52 | 48.1 |
| 14 UI | – | 2 | 2 | – | 4 | 1 | – | – | – | – | – | – | – | 27 | – | – | 36 | 75.0 |
| 15 U | – | – | – | 1 | – | 1 | 1 | 4 | 3 | – | 4 | 1 | 6 | – | 26 | 1 | 48 | 54.2 |
| Confusion | 6 | 8 | 24 | 18 | 13 | 7 | 6 | 43 | 36 | 6 | 19 | 21 | 23 | 15 | 43 | 3 | 291 | |

Table A.15 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for vehicle noise at 6 dB SNR, FEMALE speech.

| Response / Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 14 | 6 | 7 | 4 | – | 2 | – | – | 2 | 1 | – | 2 | – | 1 | 2 | 1 | 3 | – | 3 | 48 | 29.2 |
| 2 T | 5 | 13 | 2 | 3 | 2 | 1 | – | – | – | 1 | – | – | 5 | 1 | – | 6 | 6 | – | 3 | 48 | 27.1 |
| 3 K | – | 1 | 28 | 2 | – | 6 | – | – | 2 | – | 2 | – | 2 | 2 | – | – | – | 1 | 2 | 48 | 58.3 |
| 4 F | 9 | 2 | 4 | 10 | – | 3 | 1 | – | – | 1 | – | 1 | 2 | 1 | 3 | 2 | 5 | – | 4 | 48 | 20.8 |
| 5 S | 1 | – | – | 2 | 32 | – | – | – | – | 1 | – | – | – | – | – | – | 3 | 6 | 3 | 48 | 66.7 |
| 6 G | 2 | – | 2 | 3 | – | 31 | – | – | – | – | – | – | – | – | 4 | – | 2 | 1 | 3 | 48 | 64.6 |
| 7 M | – | – | 1 | – | – | – | 12 | – | 15 | 1 | 1 | 2 | 8 | 4 | 1 | 2 | – | – | 1 | 48 | 25.0 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | – | 2 | 3 | 2 | – | 19 | 5 | 2 | 2 | 9 | 2 | – | 1 | – | – | 1 | 48 | 39.6 |
| 10 L | – | – | 1 | – | – | – | 2 | – | 3 | 20 | 2 | 2 | 12 | 1 | 2 | 1 | – | – | 2 | 48 | 41.7 |
| 11 R | – | – | 3 | 2 | – | 3 | 1 | – | 1 | – | 19 | 4 | 3 | 6 | 3 | 2 | – | – | 1 | 48 | 39.6 |
| 12 W | 1 | – | – | 1 | 3 | 4 | 1 | – | – | 2 | 3 | 7 | 8 | 4 | – | 6 | 5 | – | 3 | 48 | 14.6 |
| 13 J | 1 | – | 1 | 1 | – | 1 | – | – | 2 | 1 | – | 3 | 27 | 6 | 1 | 4 | – | – | – | 48 | 56.3 |
| 14 H | 1 | – | 7 | 4 | – | 9 | 1 | – | – | 1 | – | 2 | 5 | 12 | – | 3 | 1 | – | 2 | 48 | 25.0 |
| 15 B | 6 | 2 | 4 | 8 | 1 | – | 1 | – | 2 | 1 | 1 | 5 | 4 | 1 | 3 | 4 | 1 | – | 4 | 48 | 6.3 |
| 16 D | 2 | 1 | – | 3 | 1 | – | 2 | – | 3 | 6 | 1 | 2 | 7 | 1 | 1 | 15 | 1 | 1 | 1 | 48 | 31.3 |
| 17 V | 4 | 2 | 4 | 6 | 3 | 5 | – | – | – | 1 | – | 6 | 4 | 3 | 1 | – | 7 | – | 2 | 48 | 14.6 |
| 18 Z | 1 | 3 | – | 1 | 15 | – | – | – | – | – | – | 3 | 7 | 1 | 1 | 2 | 1 | 9 | 4 | 48 | 18.8 |
| Confusion | 33 | 17 | 36 | 40 | 27 | 37 | 11 | 0 | 30 | 22 | 12 | 34 | 76 | 38 | 15 | 36 | 27 | 8 | 39 | 538 | |

| Response / Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 30 | – | 8 | – | – | – | – | – | – | – | – | – | – | 4 | 2 | 4 | 48 | 62.5 |
| 2 AU | 2 | 14 | 31 | – | – | – | – | – | – | – | – | – | – | – | – | 1 | 48 | 29.2 |
| 3 A | 3 | 5 | 73 | – | – | – | – | – | 1 | 2 | 1 | 4 | – | 3 | 3 | 1 | 96 | 76.0 |
| 4 EE | – | – | – | 33 | – | 1 | 2 | 1 | 10 | – | 1 | – | – | – | – | – | 48 | 68.8 |
| 5 IJ | – | – | – | – | 40 | – | 1 | 1 | 3 | – | – | – | – | – | – | 3 | 48 | 83.3 |
| 6 EU | – | – | – | – | – | 22 | – | 1 | 3 | 2 | 1 | 4 | 1 | 1 | 10 | 3 | 48 | 45.8 |
| 7 E | 1 | 3 | 7 | 3 | 7 | – | 43 | 1 | 13 | – | – | 3 | – | 1 | 9 | 2 | 96 | 44.8 |
| 8 IE | 1 | – | – | – | 1 | – | 2 | 20 | 4 | 1 | 3 | 1 | 9 | – | 4 | 2 | 48 | 41.7 |
| 9 I | – | – | – | – | 2 | 2 | 1 | 16 | 14 | 1 | 1 | 2 | 2 | – | 5 | 2 | 48 | 29.2 |
| 10 OO | – | 7 | 3 | – | 1 | 2 | – | 1 | – | 22 | – | 7 | – | – | 1 | 4 | 48 | 45.8 |
| 11 OE | – | – | 3 | – | – | 1 | – | 6 | 5 | 1 | 11 | 7 | 7 | – | 2 | 5 | 48 | 22.9 |
| 12 O | 1 | 1 | 6 | – | – | – | 1 | 2 | 1 | 3 | 4 | 24 | – | – | 2 | 3 | 48 | 50.0 |
| 13 UU | 1 | – | 1 | 1 | 1 | – | 1 | 12 | 4 | 1 | 3 | – | 16 | – | 5 | 2 | 48 | 33.3 |
| 14 UI | 3 | – | 1 | – | 2 | – | 3 | – | 1 | – | 1 | – | – | 32 | 2 | 3 | 48 | 66.7 |
| 15 U | – | – | – | – | 1 | 1 | 1 | 5 | 8 | – | 1 | 2 | 6 | 2 | 20 | 1 | 48 | 41.7 |
| Confusion | 12 | 16 | 60 | 4 | 15 | 7 | 12 | 46 | 53 | 11 | 16 | 30 | 25 | 11 | 45 | 39 | 402 | |

Table A.16  Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder for vehicle noise at 12 dB SNR, FEMALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1  P | 14 | 6 | 6 | 8 | – | 6 | – | – | – | – | 1 | 1 | 1 | 1 | 1 | – | 3 | – | – | 48 | 29.2 |
| 2  T | 2 | 30 | 3 | 4 | 2 | 2 | – | – | – | – | – | – | 1 | 1 | – | – | 2 | 1 | – | 48 | 62.5 |
| 3  K | – | 6 | 23 | 3 | 1 | 7 | – | – | – | – | – | 1 | 2 | 1 | – | 1 | 1 | – | 2 | 48 | 47.9 |
| 4  F | – | 2 | 1 | 19 | – | 6 | – | – | – | – | 1 | – | – | – | – | – | 19 | – | – | 48 | 39.6 |
| 5  S | – | – | – | 1 | 40 | 2 | – | – | – | – | – | – | – | – | – | – | 1 | 4 | – | 48 | 83.3 |
| 6  G | 2 | 1 | – | 1 | 1 | 34 | – | – | – | – | – | 1 | – | 1 | – | 2 | 3 | 1 | 1 | 48 | 70.8 |
| 7  M | – | – | 1 | – | – | – | 19 | – | 11 | – | – | 2 | 13 | 2 | – | – | – | – | – | 48 | 39.6 |
| 8  NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9  N | – | – | – | – | – | – | 7 | – | 18 | 7 | 7 | – | 9 | – | – | – | – | – | – | 48 | 37.5 |
| 10  L | – | 1 | – | – | – | – | – | – | 3 | 21 | 5 | – | 12 | – | 3 | 1 | – | – | 2 | 48 | 43.8 |
| 11  R | – | – | – | 3 | 1 | 1 | – | – | 1 | 5 | 23 | 2 | 4 | 2 | 1 | 2 | 3 | – | – | 48 | 47.9 |
| 12  W | 1 | – | 2 | 4 | 3 | 1 | 1 | – | 1 | 1 | 1 | 15 | 6 | 4 | 4 | 4 | – | – | – | 48 | 31.3 |
| 13  J | – | – | – | – | – | 1 | 1 | – | – | 1 | 1 | 2 | 34 | 2 | – | 5 | 1 | – | – | 48 | 70.8 |
| 14  H | – | – | 1 | 5 | – | 15 | – | – | – | – | 1 | 1 | 4 | 14 | 2 | – | 4 | – | 1 | 48 | 29.2 |
| 15  B | 4 | 1 | 1 | 7 | – | – | – | – | – | – | – | 2 | – | – | 24 | 2 | 7 | – | – | 48 | 50.0 |
| 16  D | 4 | 4 | 1 | 5 | 1 | – | – | – | 3 | – | – | 3 | 8 | – | 4 | 11 | 3 | 1 | – | 48 | 22.9 |
| 17  V | 3 | 2 | 1 | 15 | – | 3 | – | – | – | – | 2 | 1 | 2 | 1 | 1 | 4 | 13 | – | – | 48 | 27.1 |
| 18  Z | – | 2 | – | 2 | 23 | 1 | – | – | – | – | – | – | 5 | – | – | 3 | 1 | 11 | – | 48 | 22.9 |
| Confusion | 16 | 25 | 17 | 58 | 32 | 45 | 9 | 0 | 19 | 14 | 19 | 16 | 67 | 15 | 16 | 24 | 48 | 7 | 6 | 453 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1  AA | 30 | 1 | 8 | – | 4 | – | 1 | – | – | – | – | – | – | 3 | – | 1 | 48 | 62.5 |
| 2  AU | 1 | 25 | 19 | – | – | – | 1 | – | – | – | – | – | – | 2 | – | – | 48 | 52.1 |
| 3  A | – | 6 | 82 | – | – | – | 2 | – | – | 3 | – | 2 | – | – | 1 | – | 96 | 85.4 |
| 4  EE | – | – | – | 36 | – | – | 1 | 1 | 10 | – | – | – | – | – | – | – | 48 | 75.0 |
| 5  IJ | – | – | – | – | 44 | – | 4 | – | – | – | – | – | – | – | – | – | 48 | 91.7 |
| 6  EU | – | – | – | 1 | – | 31 | – | – | 1 | – | – | 1 | – | – | 12 | 2 | 48 | 64.6 |
| 7  E | – | – | 1 | 1 | 9 | 2 | 61 | – | – | – | – | 1 | – | 3 | 6 | – | 96 | 63.5 |
| 8  IE | – | – | – | – | – | – | – | 35 | 8 | – | – | – | 3 | – | 1 | 1 | 48 | 72.9 |
| 9  I | – | – | – | 5 | – | – | 1 | 9 | 31 | – | 1 | 1 | – | – | – | – | 48 | 64.6 |
| 10  OO | – | 1 | 3 | – | – | 1 | – | – | – | 24 | 1 | 11 | – | – | 7 | – | 48 | 50.0 |
| 11  OE | – | – | – | – | – | 1 | – | 6 | 3 | 1 | 19 | 4 | 11 | – | 3 | – | 48 | 39.6 |
| 12  O | – | – | 3 | – | – | 3 | – | – | – | 4 | 10 | 24 | 1 | – | 3 | – | 48 | 50.0 |
| 13  UU | – | – | 1 | – | – | – | – | 10 | 2 | – | 2 | 1 | 26 | 1 | 3 | 2 | 48 | 54.2 |
| 14  UI | 1 | – | 3 | – | 2 | 4 | – | – | – | – | – | – | – | 38 | – | – | 48 | 79.2 |
| 15  U | – | – | – | – | – | 7 | 1 | 1 | 3 | – | 2 | – | 3 | – | 31 | – | 48 | 64.6 |
| Confusion | 2 | 8 | 38 | 7 | 15 | 18 | 11 | 29 | 37 | 8 | 16 | 21 | 18 | 9 | 36 | 6 | 279 | |

Table A.17 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for aircraft noise at 6 dB SNR, FEMALE speech.

| Response<br>Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 38 | 2 | 1 | 3 | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 3 | – | 48 | 79.2 |
| 2 T | 1 | 45 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 48 | 93.8 |
| 3 K | 1 | – | 47 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 97.9 |
| 4 F | – | 3 | – | 29 | – | 2 | – | – | – | – | – | – | – | 1 | 1 | – | 10 | 1 | 1 | 48 | 60.4 |
| 5 S | – | – | – | 1 | 36 | – | – | – | – | – | – | – | – | – | – | – | 1 | 10 | – | 48 | 75.0 |
| 6 G | – | – | – | 2 | 2 | 42 | – | – | – | – | – | – | – | – | – | – | 1 | 1 | – | 48 | 87.5 |
| 7 M | – | – | – | – | – | – | 37 | – | 7 | 1 | – | 1 | 2 | – | – | – | – | – | – | 48 | 77.1 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | – | – | – | 7 | – | 40 | – | – | – | 1 | – | – | – | – | – | – | 48 | 83.3 |
| 10 L | – | – | – | – | – | – | – | – | 1 | 42 | – | 2 | 3 | – | – | – | – | – | – | 48 | 87.5 |
| 11 R | – | – | – | – | – | – | – | – | – | – | 45 | 2 | – | – | – | 1 | – | 1 | – | 48 | 93.8 |
| 12 W | – | – | – | – | – | 1 | – | – | 4 | – | – | 36 | – | 4 | 3 | – | – | – | – | 48 | 75.0 |
| 13 J | – | – | – | – | – | – | 1 | – | – | – | – | 1 | 41 | 1 | – | 1 | 2 | – | 1 | 48 | 85.4 |
| 14 H | 1 | – | 2 | 1 | – | 2 | – | – | – | – | 3 | 1 | 2 | 36 | – | – | – | – | – | 48 | 75.0 |
| 15 B | 2 | – | – | – | – | – | – | – | – | – | – | 4 | 1 | – | 38 | 2 | 1 | – | – | 48 | 79.2 |
| 16 D | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 3 | 44 | – | – | – | 48 | 91.7 |
| 17 V | 1 | 1 | – | 19 | 3 | 2 | – | – | – | 1 | 1 | – | 1 | – | 1 | 3 | 12 | 3 | – | 48 | 25.0 |
| 18 Z | – | – | – | – | 25 | – | – | – | – | – | – | – | 1 | – | – | – | – | 22 | – | 48 | 45.8 |
| Confusion | 6 | 6 | 4 | 26 | 30 | 7 | 8 | 0 | 12 | 2 | 4 | 11 | 12 | 6 | 9 | 6 | 19 | 16 | 2 | 186 | |

| Response<br>Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 38 | – | – | – | – | 1 | – | – | – | – | – | – | – | – | 9 | – | 48 | 79.2 |
| 2 AU | 1 | 40 | 3 | – | – | 2 | – | – | – | – | – | 1 | – | 1 | – | – | 48 | 83.3 |
| 3 A | – | 4 | 88 | – | – | – | – | – | – | – | – | 4 | – | – | – | – | 96 | 91.7 |
| 4 EE | – | – | – | 43 | – | – | 1 | – | 4 | – | – | – | – | – | – | – | 48 | 89.6 |
| 5 IJ | – | – | – | 1 | 46 | – | – | – | – | – | – | – | – | 1 | – | – | 48 | 95.8 |
| 6 EU | – | – | – | – | – | 39 | – | – | – | – | 1 | – | 1 | – | 7 | – | 48 | 81.3 |
| 7 E | – | – | 7 | 1 | 3 | – | 74 | – | 1 | – | 1 | – | 3 | – | 5 | 1 | 96 | 77.1 |
| 8 IE | – | – | – | – | – | – | – | 41 | 7 | – | – | – | – | – | – | – | 48 | 85.4 |
| 9 I | – | – | – | 8 | – | – | – | 3 | 37 | – | – | – | – | – | – | – | 48 | 77.1 |
| 10 OO | – | 1 | 1 | – | – | 1 | – | – | – | 40 | – | 4 | – | – | 1 | – | 48 | 83.3 |
| 11 OE | – | – | – | – | – | – | – | – | 1 | – | 43 | 2 | 1 | – | 1 | – | 48 | 89.6 |
| 12 O | – | – | – | – | – | – | – | – | – | 8 | – | 35 | 4 | – | – | 1 | 48 | 72.9 |
| 13 UU | – | – | – | – | – | 2 | – | – | – | – | 6 | – | 35 | – | 5 | – | 48 | 72.9 |
| 14 UI | – | – | – | – | – | 5 | – | – | – | – | – | – | – | 43 | – | – | 48 | 89.6 |
| 15 U | – | – | – | – | – | 8 | – | – | – | 2 | – | – | 1 | – | 37 | – | 48 | 77.1 |
| Confusion | 1 | 5 | 11 | 10 | 3 | 19 | 1 | 3 | 13 | 10 | 8 | 11 | 10 | 11 | 19 | 2 | 137 | |

Table A.18 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for aircraft noise at 12 dB SNR, FEMALE speech.

```
Response  P  T  K  F  S  G  M NG  N  L  R  W  J  H  B  D  V  Z ??  Tot    %
Stimulus
 1  P    39  -  6  2  -  -  -  -  -  -  -  -  -  -  -  1  -  -  -   48   81.3
 2  T     - 48  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -   48  100.0
 3  K     1  - 46  -  -  1  -  -  -  -  -  -  -  -  -  -  -  -  -   48   95.8
 4  F     -  -  - 32  1  1  -  -  -  -  -  -  -  -  -  - 14  -  -   48   66.7
 5  S     -  -  -  - 43  -  -  -  -  -  -  -  -  -  -  -  -  5  -   48   89.6
 6  G     -  -  -  -  1 46  -  -  -  -  -  -  -  -  -  -  -  -  1   48   95.8
 7  M     -  -  -  -  -  - 43  -  3  1  -  1  -  -  -  -  -  -  -   48   89.6
 8 NG     -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -    0   --.-
 9  N     -  -  -  -  -  -  2  - 46  -  -  -  -  -  -  -  -  -  -   48   95.8
10  L     -  -  -  -  -  -  -  - 48  -  -  -  -  -  -  -  -  -      48  100.0
11  R     -  -  -  -  -  -  -  -  - 48  -  -  -  -  -  -  -  -  -   48  100.0
12  W     -  -  -  -  -  -  1  -  -  -  - 45  -  -  2  -  -  -  -   48   93.8
13  J     -  -  -  -  -  -  -  -  -  1  -  - 47  -  -  -  -  -  -   48   97.9
14  H     -  -  -  -  -  -  -  -  -  -  -  -  1 47  -  -  -  -  -   48   97.9
15  B     -  -  -  -  -  -  -  -  -  -  -  4  -  - 43  1  -  -  -   48   89.6
16  D     -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 48  -  -  -   48  100.0
17  V     -  -  - 26  -  1  -  -  -  -  -  -  1  -  -  - 20  -  -   48   41.7
18  Z     -  -  -  - 34  -  -  -  -  -  -  -  -  -  -  -  - 14  -   48   29.2
Confusion  1  0  6 28 36  3  3  0  3  2  0  5  2  0  2  2 14  5  1  113
```

```
Response  AA AU  A EE IJ EU  E IE  I OO OE  O UU UI  U ??  Tot    %
Stimulus
 1  AA    48  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -   48  100.0
 2  AU     - 39  8  -  -  -  -  -  -  -  -  -  -  -  -  1   48   81.3
 3  A      -  3 86  -  -  -  1  -  -  -  -  2  -  -  -  -   92   93.5
 4  EE     -  -  - 43  -  -  -  -  5  -  -  -  -  -  -  -   48   89.6
 5  IJ     -  -  -  - 47  1  -  -  -  -  -  -  -  -  -  -   48   97.9
 6  EU     -  -  -  -  - 43  -  -  -  -  -  -  -  -  5  -   48   89.6
 7  E      -  -  -  -  4  - 96  -  1  -  -  1  -  2  -  -  104   92.3
 8  IE     -  -  -  2  -  -  - 41  4  -  -  -  1  -  -  -   48   85.4
 9  I      -  -  -  4  -  -  -  1 36  -  -  -  -  -  3  -   44   81.8
10  OO     -  -  -  -  -  -  -  -  - 41  -  7  -  -  -  -   48   85.4
11  OE     -  -  -  -  -  -  -  -  -  - 46  2  -  -  -  -   48   95.8
12  O      -  -  -  -  -  -  -  -  -  6  - 42  -  -  -  -   48   87.5
13  UU     -  -  -  -  -  1  -  -  -  -  -  - 50  -  1  -   52   96.2
14  UI     -  -  -  -  -  2  1  -  -  -  -  -  - 41  -  -   44   93.2
15  U      -  -  -  -  -  1  -  -  -  1  -  2  - 44  -   48   91.7
Confusion   0  3  8  6  4  5  2  1 10  6  1 12  3  2  9  1   73
```

Table A.19 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for vehicle noise at 6 dB SNR, FEMALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 37 | 1 | 6 | 2 | – | – | – | – | – | – | – | – | – | – | – | 2 | – | – | – | 48 | 77.1 |
| 2 T | – | 44 | – | – | – | – | – | – | – | – | – | – | – | – | – | 4 | – | – | – | 48 | 91.7 |
| 3 K | 1 | 4 | 43 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 89.6 |
| 4 F | – | 1 | – | 29 | – | 1 | – | – | – | – | – | – | – | – | – | – | 16 | – | 1 | 48 | 60.4 |
| 5 S | – | – | – | – | 34 | – | – | – | – | – | – | – | – | – | – | – | – | 6 | – | 40 | 85.0 |
| 6 G | – | – | – | – | – | 48 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 100.0 |
| 7 M | – | – | – | – | – | – | 31 | – | 15 | – | – | 2 | – | – | – | – | – | – | – | 48 | 64.6 |
| 8 NG | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 | --.- |
| 9 N | – | – | – | – | – | – | 5 | – | 41 | – | – | – | – | – | – | – | – | – | 2 | 48 | 85.4 |
| 10 L | – | – | – | – | – | – | – | – | 1 | 45 | – | – | 2 | – | – | – | – | – | – | 48 | 93.8 |
| 11 R | – | – | – | – | – | – | – | – | – | – | 43 | – | 3 | – | 1 | 1 | – | – | – | 48 | 89.6 |
| 12 W | – | – | – | – | – | – | 4 | – | – | 2 | 4 | 36 | 1 | – | 1 | – | – | – | – | 48 | 75.0 |
| 13 J | – | – | – | – | 3 | – | – | – | – | – | – | – | 42 | 2 | – | – | – | 1 | – | 48 | 87.5 |
| 14 H | – | – | – | 1 | – | – | – | – | – | – | 1 | – | – | 45 | – | 1 | – | – | – | 48 | 93.8 |
| 15 B | 1 | – | – | 1 | – | – | – | – | – | – | – | 8 | – | 1 | 37 | – | – | – | – | 48 | 77.1 |
| 16 D | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 2 | 45 | – | – | – | 48 | 93.8 |
| 17 V | – | – | – | 26 | 2 | 1 | – | – | – | – | – | – | – | – | – | – | 18 | 1 | – | 48 | 37.5 |
| 18 Z | – | – | – | – | 44 | – | – | – | – | – | – | – | – | – | – | – | – | 12 | – | 56 | 21.4 |
| Confusion | 2 | 6 | 6 | 30 | 49 | 2 | 9 | 0 | 16 | 2 | 5 | 10 | 7 | 3 | 6 | 5 | 17 | 8 | 3 | 186 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 43 | 1 | – | – | 1 | – | – | – | – | – | – | – | – | 3 | – | – | 48 | 89.6 |
| 2 AU | – | 43 | 5 | – | – | – | – | – | – | – | – | – | – | – | – | – | 48 | 89.6 |
| 3 A | – | 6 | 89 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 96 | 92.7 |
| 4 EE | – | – | – | 42 | – | – | – | 1 | 5 | – | – | – | – | – | – | – | 48 | 87.5 |
| 5 IJ | – | – | – | 5 | 43 | – | – | – | – | – | – | – | – | – | – | – | 48 | 89.6 |
| 6 EU | – | – | – | – | – | 55 | – | – | – | – | – | – | – | – | – | 1 | 56 | 98.2 |
| 7 E | – | – | – | 5 | 10 | – | 79 | – | 2 | – | – | – | – | – | – | – | 96 | 82.3 |
| 8 IE | – | – | – | – | – | – | – | 44 | 3 | – | – | – | – | – | – | 1 | 48 | 91.7 |
| 9 I | – | – | – | – | – | – | – | 2 | 42 | – | – | 1 | – | – | 3 | – | 48 | 87.5 |
| 10 OO | – | – | – | – | – | – | – | – | – | 44 | 2 | 2 | – | – | – | – | 48 | 91.7 |
| 11 OE | – | – | – | – | – | – | – | 1 | – | – | 46 | – | 1 | – | – | – | 48 | 95.8 |
| 12 O | – | – | 1 | – | – | – | 1 | – | – | 10 | 1 | 35 | – | – | – | – | 48 | 72.9 |
| 13 UU | – | – | – | – | – | 1 | – | – | – | – | 3 | – | 42 | – | 1 | 1 | 48 | 87.5 |
| 14 UI | – | – | – | 3 | 1 | 1 | 1 | – | – | – | – | – | – | 34 | – | – | 40 | 85.0 |
| 15 U | – | – | – | – | – | – | – | – | – | – | – | – | 5 | – | 43 | – | 48 | 89.6 |
| Confusion | 0 | 7 | 6 | 13 | 12 | 2 | 2 | 4 | 10 | 10 | 6 | 3 | 6 | 4 | 4 | 3 | 92 | |

Table A.20 Confusion matrix for the initial consonants and vowels transmitted through the noise pre-processor for vehicle noise at 12 dB SNR, FEMALE speech.

| Response | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stimulus | | | | | | | | | | | | | | | | | | | | | |
| 1 P | 39 | 4 | 1 | 3 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 48 | 81.3 |
| 2 T | 3 | 44 | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 48 | 91.7 |
| 3 K | 3 | - | 44 | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 48 | 91.7 |
| 4 F | - | - | - | 28 | - | - | - | - | - | - | - | - | - | - | - | - | 16 | - | - | 44 | 63.6 |
| 5 S | - | 2 | - | - | 38 | - | - | - | - | - | - | - | - | - | - | - | - | 8 | - | 48 | 79.2 |
| 6 G | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 7 M | - | - | - | - | - | - | 41 | - | 5 | - | - | 1 | - | 1 | - | - | - | - | - | 48 | 85.4 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 10 L | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 11 R | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | - | - | 48 | 100.0 |
| 12 W | - | - | - | - | - | - | - | - | - | 1 | 2 | 38 | - | 1 | 5 | 1 | - | - | - | 48 | 79.2 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | - | 48 | - | - | - | - | - | - | 48 | 100.0 |
| 14 H | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 3 | 40 | - | 1 | 2 | - | - | 48 | 83.3 |
| 15 B | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 43 | 2 | - | - | - | 48 | 89.6 |
| 16 D | - | 3 | - | - | - | - | - | - | - | 1 | - | 3 | 1 | - | - | 40 | - | - | - | 48 | 83.3 |
| 17 V | - | - | - | 28 | 2 | - | - | - | - | - | - | - | - | - | - | - | 22 | - | - | 52 | 42.3 |
| 18 Z | - | - | - | - | 35 | - | - | - | - | - | - | - | 3 | - | - | - | - | 10 | - | 48 | 20.8 |
| Confusion | 6 | 9 | 1 | 32 | 37 | 0 | 0 | 0 | 5 | 2 | 2 | 8 | 7 | 4 | 6 | 4 | 18 | 8 | 0 | 149 | |

| Response | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stimulus | | | | | | | | | | | | | | | | | | |
| 1 AA | 42 | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 44 | 95.5 |
| 2 AU | - | 40 | 6 | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | 48 | 83.3 |
| 3 A | - | 1 | 95 | - | - | - | - | - | - | - | - | - | - | - | - | - | 96 | 99.0 |
| 4 EE | - | - | - | 46 | - | - | - | - | 6 | - | - | - | - | - | - | - | 52 | 88.5 |
| 5 IJ | - | - | - | 4 | 44 | - | - | - | - | - | - | - | - | - | - | - | 48 | 91.7 |
| 6 EU | - | - | - | - | - | 43 | - | - | - | - | - | - | - | - | 5 | - | 48 | 89.6 |
| 7 E | 1 | - | - | 1 | 6 | - | 86 | - | - | - | - | - | - | 1 | 1 | - | 96 | 89.6 |
| 8 IE | - | - | - | - | - | - | - | 39 | 9 | - | - | - | - | - | - | - | 48 | 81.3 |
| 9 I | - | - | - | 2 | - | - | - | 1 | 45 | - | - | - | - | - | - | - | 48 | 93.8 |
| 10 OO | - | - | - | - | - | - | - | - | - | 44 | - | 4 | - | - | - | - | 48 | 91.7 |
| 11 OE | - | - | - | - | - | - | - | - | - | - | 44 | 1 | 2 | - | 1 | - | 48 | 91.7 |
| 12 O | - | - | - | - | - | - | - | - | - | 7 | 1 | 40 | - | - | - | - | 48 | 83.3 |
| 13 UU | - | - | - | - | - | 1 | - | 1 | - | - | - | - | 44 | - | 2 | - | 48 | 91.7 |
| 14 UI | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 47 | - | - | 48 | 97.9 |
| 15 U | - | - | - | - | - | 2 | - | - | 6 | - | - | - | 1 | - | 39 | - | 48 | 81.3 |
| Confusion | 1 | 1 | 6 | 7 | 6 | 4 | 0 | 2 | 21 | 7 | 1 | 6 | 3 | 3 | 10 | 0 | 78 | |

Table A.21 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for aircraft noise at 6 dB SNR, FEMALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 20 | 6 | 2 | 8 | 1 | 6 | - | - | - | - | - | - | 2 | 1 | 1 | - | 1 | - | - | 48 | 41.7 |
| 2 T | 6 | 21 | 10 | 3 | 2 | 3 | - | - | 1 | 1 | - | - | - | - | - | - | - | 1 | - | 48 | 43.8 |
| 3 K | 4 | 1 | 32 | 2 | - | 4 | - | - | - | - | - | - | 1 | 3 | - | - | - | 1 | - | 48 | 66.7 |
| 4 F | 2 | 2 | 1 | 13 | 3 | 19 | - | - | - | - | - | 1 | - | - | - | - | 6 | 1 | - | 48 | 27.1 |
| 5 S | - | - | - | - | 42 | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 4 | - | 48 | 87.5 |
| 6 G | - | - | 1 | - | 6 | 40 | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 48 | 83.3 |
| 7 M | - | - | - | - | - | - | 18 | - | 16 | 1 | - | 1 | 12 | - | - | - | - | - | - | 48 | 37.5 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 7 | - | 22 | 1 | - | - | 18 | - | - | - | - | - | - | 48 | 45.8 |
| 10 L | - | - | - | - | - | - | - | - | 6 | 19 | 1 | - | 20 | 2 | - | - | - | - | - | 48 | 39.6 |
| 11 R | - | - | - | 1 | - | - | - | - | 1 | 1 | 31 | 8 | 5 | 1 | - | - | - | - | - | 48 | 64.6 |
| 12 W | - | - | - | 1 | - | - | - | - | 1 | - | 6 | 22 | 15 | 2 | - | - | - | - | 1 | 48 | 45.8 |
| 13 J | - | - | - | - | - | - | - | - | - | 1 | 2 | 11 | 34 | - | - | - | - | - | - | 48 | 70.8 |
| 14 H | 2 | - | - | - | - | 1 | 6 | - | 2 | - | 5 | - | 16 | 14 | - | 1 | 1 | - | - | 48 | 29.2 |
| 15 B | 2 | - | - | 1 | 2 | - | - | - | - | - | 2 | 11 | 8 | - | 19 | 2 | 1 | - | - | 48 | 39.6 |
| 16 D | - | - | - | 2 | 7 | - | - | - | - | 2 | 3 | 5 | 13 | 1 | 5 | 8 | 1 | 1 | - | 48 | 16.7 |
| 17 V | 3 | 2 | - | 7 | 4 | 8 | - | - | 1 | - | 3 | 4 | 6 | 1 | - | - | 8 | 1 | - | 48 | 16.7 |
| 18 Z | - | - | - | - | 26 | - | - | - | - | - | 1 | - | 10 | - | - | - | 1 | 10 | - | 48 | 20.8 |
| Confusion | 19 | 11 | 14 | 25 | 51 | 42 | 13 | 0 | 28 | 7 | 23 | 41 | 126 | 11 | 6 | 3 | 12 | 10 | 1 | 443 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 39 | - | 2 | - | - | - | - | - | - | - | - | - | - | 7 | - | - | 48 | 81.3 |
| 2 AU | 1 | 28 | 15 | - | - | - | 3 | - | - | 1 | - | - | - | - | - | - | 48 | 58.3 |
| 3 A | 1 | 4 | 84 | - | - | 1 | 1 | 1 | - | - | - | 1 | 1 | 1 | 1 | - | 96 | 87.5 |
| 4 EE | - | - | - | 30 | - | - | 1 | 6 | 11 | - | - | - | - | - | - | - | 48 | 62.5 |
| 5 IJ | - | - | - | 2 | 35 | - | 5 | 1 | - | - | - | - | - | 5 | - | - | 48 | 72.9 |
| 6 EU | - | 1 | - | 3 | 1 | 22 | 1 | - | - | 2 | - | 3 | 2 | 2 | 11 | - | 48 | 45.8 |
| 7 E | 1 | 2 | 4 | 2 | 9 | 1 | 48 | 4 | 3 | 3 | - | 8 | 3 | 2 | 6 | - | 96 | 50.0 |
| 8 IE | - | - | - | - | - | - | 1 | 34 | 4 | - | 2 | - | 6 | - | 1 | - | 48 | 70.8 |
| 9 I | - | - | - | 3 | 1 | - | - | 19 | 21 | - | 2 | - | 1 | - | 1 | - | 48 | 43.8 |
| 10 OO | - | - | 4 | 1 | 1 | 1 | 1 | 3 | 1 | 21 | 3 | 10 | - | - | 2 | - | 48 | 43.8 |
| 11 OE | - | - | - | - | - | - | - | 9 | 5 | - | 16 | 5 | 11 | - | 2 | - | 48 | 33.3 |
| 12 O | - | - | 10 | 1 | - | - | 1 | 4 | - | 2 | 5 | 24 | 1 | - | - | - | 48 | 50.0 |
| 13 UU | - | - | - | 2 | - | - | 1 | 12 | 6 | - | - | 1 | 23 | - | 3 | - | 48 | 47.9 |
| 14 UI | 3 | 1 | 3 | - | 4 | 1 | - | - | - | - | - | 1 | - | 35 | - | - | 48 | 72.9 |
| 15 U | - | - | - | - | - | 4 | 1 | 2 | 6 | 2 | 3 | 3 | 6 | 3 | 18 | - | 48 | 37.5 |
| Confusion | 6 | 8 | 38 | 14 | 16 | 8 | 16 | 61 | 36 | 10 | 15 | 32 | 31 | 20 | 27 | 0 | 338 | |

Table A.22 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for aircraft noise at 12 dB SNR, FEMALE speech.

| Response<br>Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 30 | 4 | 1 | 6 | - | 1 | - | - | - | - | - | - | - | - | - | - | 5 | - | 1 | 48 | 62.5 |
| 2 T | 9 | 25 | 3 | 2 | - | 3 | - | - | - | - | - | - | - | 2 | - | 1 | 3 | - | - | 48 | 52.1 |
| 3 K | - | - | 42 | - | 1 | 3 | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | 48 | 87.5 |
| 4 F | 2 | 1 | 1 | 18 | - | 14 | - | - | - | - | - | - | - | - | - | - | 12 | - | - | 48 | 37.5 |
| 5 S | - | - | - | - | 34 | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 12 | - | 48 | 70.8 |
| 6 G | - | - | - | - | 2 | 43 | - | - | - | - | - | - | - | 1 | - | - | - | 2 | - | 48 | 89.6 |
| 7 M | - | - | - | - | - | - | 17 | - | 21 | - | - | 1 | 9 | - | - | - | - | - | - | 48 | 35.4 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 3 | - | 28 | 1 | - | 1 | 14 | - | 1 | - | - | - | - | 48 | 58.3 |
| 10 L | - | - | - | - | - | - | - | - | 13 | 18 | 2 | 2 | 12 | - | - | - | - | 1 | - | 48 | 37.5 |
| 11 R | - | - | - | - | - | - | - | - | - | 3 | 34 | 5 | 1 | 3 | - | 1 | 1 | - | - | 48 | 70.8 |
| 12 W | 1 | - | - | 1 | - | 1 | - | - | 1 | 4 | - | 23 | 15 | 1 | - | - | - | 1 | - | 48 | 47.9 |
| 13 J | - | - | - | - | - | - | - | - | - | - | - | 4 | 41 | - | - | - | - | 3 | - | 48 | 85.4 |
| 14 H | - | - | - | 1 | 1 | 1 | 3 | - | 1 | - | - | 3 | 7 | 27 | - | - | 4 | - | - | 48 | 56.3 |
| 15 B | 4 | - | - | - | - | - | - | - | 1 | 3 | 3 | 8 | 4 | 1 | 22 | 1 | 1 | - | - | 48 | 45.8 |
| 16 D | - | 1 | - | - | 1 | - | - | - | - | - | 1 | 9 | 14 | - | 4 | 18 | - | - | - | 48 | 37.5 |
| 17 V | 2 | - | - | 11 | 7 | 9 | - | - | - | - | 2 | 2 | 4 | 1 | - | - | 8 | 2 | - | 48 | 16.7 |
| 18 Z | - | - | - | - | 28 | 3 | - | - | - | - | - | - | 1 | - | - | - | - | 16 | - | 48 | 33.3 |
| Confusion | 18 | 6 | 5 | 21 | 40 | 36 | 6 | 0 | 37 | 11 | 8 | 35 | 81 | 10 | 5 | 4 | 27 | 21 | 1 | 372 | |

| Response<br>Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 41 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | 4 | - | - | 48 | 85.4 |
| 2 AU | - | 24 | 19 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 44 | 54.5 |
| 3 A | - | 3 | 80 | - | - | - | 1 | 1 | - | - | 2 | 5 | 2 | 1 | - | 1 | 96 | 83.3 |
| 4 EE | - | - | - | 26 | - | 1 | - | 7 | 12 | - | - | - | 2 | - | - | - | 48 | 54.2 |
| 5 IJ | - | - | - | 2 | 38 | - | - | - | - | - | - | - | 1 | 7 | - | - | 48 | 79.2 |
| 6 EU | - | - | 1 | 1 | - | 28 | - | 1 | 4 | - | - | 1 | 3 | - | 9 | - | 48 | 58.3 |
| 7 E | - | - | - | 1 | 14 | - | 59 | 4 | 1 | 1 | 2 | 6 | - | 7 | 1 | - | 96 | 61.5 |
| 8 IE | - | 1 | - | - | - | - | - | 35 | 5 | - | - | - | 5 | - | 2 | - | 48 | 72.9 |
| 9 I | - | - | - | 2 | - | 2 | 1 | 20 | 18 | - | 2 | - | 2 | - | 1 | - | 48 | 37.5 |
| 10 OO | - | 1 | 2 | - | - | - | - | - | - | 36 | 1 | 7 | - | - | 1 | - | 48 | 75.0 |
| 11 OE | - | - | - | 3 | - | - | 1 | 7 | 4 | - | 23 | 3 | 6 | - | 1 | - | 48 | 47.9 |
| 12 O | - | - | 6 | - | - | - | - | - | - | 1 | - | 41 | - | - | - | - | 48 | 85.4 |
| 13 UU | - | - | - | 1 | - | 3 | - | 7 | 10 | - | 2 | - | 21 | - | 4 | - | 48 | 43.8 |
| 14 UI | - | 2 | 3 | - | 3 | - | 3 | - | - | - | - | - | - | 41 | - | - | 52 | 78.8 |
| 15 U | - | - | - | - | - | 2 | 2 | 9 | 3 | - | - | 3 | 8 | - | 21 | - | 48 | 43.8 |
| Confusion | 0 | 9 | 32 | 10 | 17 | 8 | 8 | 56 | 39 | 3 | 9 | 25 | 29 | 19 | 19 | 1 | 284 | |

Table A.23 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for vehicle noise at 6 dB SNR, FEMALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 28 | 2 | 3 | 3 | - | 3 | - | - | - | 1 | - | - | 1 | 2 | 1 | 1 | 3 | - | - | 48 | 58.3 |
| 2 T | 2 | 29 | 1 | 1 | 1 | 1 | - | - | - | - | - | 2 | 1 | - | - | 3 | 7 | - | - | 48 | 60.4 |
| 3 K | - | 3 | 35 | - | - | 8 | - | - | - | - | 2 | - | - | - | - | - | - | - | - | 48 | 72.9 |
| 4 F | 2 | 4 | - | 19 | 1 | 10 | - | - | - | - | - | - | 1 | 3 | - | - | 7 | 1 | - | 48 | 39.6 |
| 5 S | - | - | - | - | 39 | - | - | - | - | - | - | - | - | - | - | - | 1 | 8 | - | 48 | 81.3 |
| 6 G | - | - | - | 1 | - | 45 | - | - | - | - | - | - | 2 | - | - | - | - | - | - | 48 | 93.8 |
| 7 M | - | - | - | - | - | - | 10 | - | 16 | 4 | - | 3 | 15 | - | - | - | - | - | - | 48 | 20.8 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 4 | - | 24 | 4 | - | - | 16 | - | - | - | - | - | - | 48 | 50.0 |
| 10 L | - | - | - | - | - | - | 2 | - | 5 | 17 | 2 | 3 | 18 | 1 | - | - | - | - | - | 48 | 35.4 |
| 11 R | - | - | - | 2 | 1 | 3 | 2 | - | - | - | 33 | 1 | 4 | - | - | 1 | - | - | 1 | 48 | 68.8 |
| 12 W | - | - | - | 1 | - | - | - | - | - | 1 | 2 | 26 | 11 | 5 | - | 2 | - | - | - | 48 | 54.2 |
| 13 J | - | - | - | - | 1 | - | - | - | - | - | - | 6 | 39 | 2 | - | - | - | - | - | 48 | 81.3 |
| 14 H | - | 1 | - | 3 | - | 6 | - | - | 2 | - | 1 | 1 | 7 | 26 | - | - | - | 1 | - | 48 | 54.2 |
| 15 B | - | - | - | 3 | - | - | - | - | - | - | - | 17 | 2 | - | 20 | 6 | - | - | - | 48 | 41.7 |
| 16 D | - | 3 | - | - | 1 | - | - | - | - | - | - | 3 | 4 | - | 6 | 30 | - | 1 | - | 48 | 62.5 |
| 17 V | 1 | - | 1 | 10 | 3 | 7 | - | - | 1 | 1 | - | 7 | - | - | - | - | 14 | 3 | - | 48 | 29.2 |
| 18 Z | - | - | - | - | 28 | 1 | - | - | - | - | 2 | - | 6 | - | - | - | - | 11 | - | 48 | 22.9 |
| Confusion | 5 | 13 | 5 | 24 | 36 | 39 | 8 | 0 | 24 | 11 | 9 | 43 | 88 | 13 | 7 | 13 | 18 | 14 | 1 | 371 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 41 | - | 5 | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 48 | 85.4 |
| 2 AU | - | 33 | 12 | - | - | - | - | - | - | 2 | - | - | - | 1 | - | - | 48 | 68.8 |
| 3 A | - | 2 | 90 | - | - | - | - | - | - | 1 | - | 3 | - | - | - | - | 96 | 93.8 |
| 4 EE | - | - | - | 39 | - | - | 2 | 2 | 5 | - | - | - | - | - | - | - | 48 | 81.3 |
| 5 IJ | - | - | - | - | 44 | - | 1 | - | 1 | - | - | - | 2 | - | - | - | 48 | 91.7 |
| 6 EU | - | - | - | 1 | - | 43 | - | - | - | - | - | - | - | - | 3 | 1 | 48 | 89.6 |
| 7 E | - | - | - | 2 | 6 | 2 | 63 | 2 | 9 | - | - | - | 3 | 2 | 7 | - | 96 | 65.6 |
| 8 IE | - | - | - | - | - | - | - | 30 | 8 | - | - | - | 10 | - | - | - | 48 | 62.5 |
| 9 I | - | - | - | 3 | - | - | 3 | 6 | 31 | - | 2 | - | 3 | - | - | - | 48 | 64.6 |
| 10 OO | - | 3 | 5 | - | - | - | - | - | - | 31 | 2 | 4 | 3 | - | - | - | 48 | 64.6 |
| 11 OE | - | - | - | 1 | - | 1 | - | 4 | 1 | - | 17 | 2 | 10 | - | 12 | - | 48 | 35.4 |
| 12 O | - | - | 7 | - | - | - | - | - | - | 12 | 2 | 26 | - | 1 | - | - | 48 | 54.2 |
| 13 UU | - | - | - | 2 | - | - | - | 9 | 2 | - | 3 | - | 26 | - | 2 | - | 44 | 59.1 |
| 14 UI | - | 6 | - | - | 2 | - | 2 | - | - | - | - | - | - | 38 | - | - | 48 | 79.2 |
| 15 U | - | - | - | - | - | - | 1 | 6 | 8 | 1 | 1 | - | 9 | - | 26 | - | 52 | 50.0 |
| Confusion | 0 | 11 | 29 | 9 | 8 | 3 | 9 | 29 | 34 | 16 | 10 | 9 | 40 | 6 | 24 | 1 | 238 | |

Table A.24 Confusion matrix for the initial consonants and vowels transmitted through the MELP speech coder combined with the noise pre-processor for vehicle noise at 12 dB SNR, FEMALE speech.

| Response Stimulus | P | T | K | F | S | G | M | NG | N | L | R | W | J | H | B | D | V | Z | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 P | 27 | 2 | - | 7 | - | 1 | - | - | - | - | - | 2 | - | 4 | 1 | - | 4 | - | - | 48 | 56.3 |
| 2 T | 3 | 35 | 6 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - | 48 | 72.9 |
| 3 K | - | - | 43 | 1 | - | 3 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 48 | 89.6 |
| 4 F | - | - | 1 | 21 | 3 | 13 | - | - | - | - | - | - | - | - | - | - | 10 | - | - | 48 | 43.8 |
| 5 S | - | - | - | - | 41 | - | - | - | - | - | - | - | - | - | - | - | - | 7 | - | 48 | 85.4 |
| 6 G | - | - | - | - | - | 47 | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 48 | 97.9 |
| 7 M | - | - | - | - | - | - | 17 | - | 16 | 3 | - | 1 | 11 | - | - | - | - | - | - | 48 | 35.4 |
| 8 NG | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | --.- |
| 9 N | - | - | - | - | - | - | 8 | - | 20 | 1 | 2 | 1 | 16 | - | - | - | - | - | - | 48 | 41.7 |
| 10 L | - | - | - | - | - | - | 2 | - | 6 | 20 | 1 | 4 | 15 | - | - | - | - | - | - | 48 | 41.7 |
| 11 R | - | - | - | - | - | - | - | - | 1 | 1 | 33 | 7 | 3 | 2 | 1 | - | - | - | - | 48 | 68.8 |
| 12 W | - | - | - | - | - | - | 1 | 1 | - | - | - | 33 | 6 | 6 | 1 | - | - | - | - | 48 | 68.8 |
| 13 J | - | - | - | - | 2 | - | - | - | - | - | - | 1 | 45 | - | - | - | - | - | - | 48 | 93.8 |
| 14 H | - | - | 1 | - | - | 1 | - | - | - | - | - | - | 4 | 41 | - | - | 1 | - | - | 48 | 85.4 |
| 15 B | 2 | - | - | 2 | - | - | 1 | - | - | 1 | 4 | 24 | 5 | 1 | 7 | - | 1 | - | - | 48 | 14.6 |
| 16 D | 1 | 1 | - | 1 | 1 | - | - | - | - | - | - | 10 | 4 | - | 2 | 28 | - | - | - | 48 | 58.3 |
| 17 V | 1 | - | 1 | 17 | 1 | 12 | - | - | - | - | 4 | 1 | - | 1 | - | - | 9 | 1 | - | 48 | 18.8 |
| 18 Z | - | - | - | 1 | 34 | - | - | - | - | - | - | - | 5 | - | - | - | - | 8 | - | 48 | 16.7 |
| Confusion | 7 | 3 | 9 | 30 | 41 | 31 | 12 | 0 | 23 | 6 | 11 | 51 | 69 | 15 | 5 | 3 | 17 | 8 | 0 | 341 | |

| Response Stimulus | AA | AU | A | EE | IJ | EU | E | IE | I | OO | OE | O | UU | UI | U | ?? | Tot | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 AA | 45 | - | 2 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 48 | 93.8 |
| 2 AU | - | 29 | 13 | - | - | - | - | - | - | 3 | - | 1 | - | 2 | - | - | 48 | 60.4 |
| 3 A | - | 3 | 88 | - | - | - | 1 | - | - | 2 | 1 | 1 | - | - | - | - | 96 | 91.7 |
| 4 EE | - | - | - | 35 | - | 1 | - | 7 | 4 | - | - | - | - | - | 1 | - | 48 | 72.9 |
| 5 IJ | - | - | - | 2 | 38 | - | - | 3 | 1 | - | - | - | 1 | 3 | - | - | 48 | 79.2 |
| 6 EU | - | - | - | 1 | - | 36 | - | - | - | - | - | - | 3 | 3 | 5 | - | 48 | 75.0 |
| 7 E | - | - | - | 1 | 2 | 1 | 68 | 4 | 5 | - | 1 | 1 | 4 | 2 | 7 | - | 96 | 70.8 |
| 8 IE | - | - | - | 1 | - | - | - | 31 | 5 | - | 2 | - | 8 | - | 1 | - | 48 | 64.6 |
| 9 I | - | - | - | 7 | - | - | 2 | 9 | 29 | - | - | - | - | - | 1 | - | 48 | 60.4 |
| 10 OO | - | 1 | - | 2 | - | - | - | - | - | 35 | 4 | 5 | - | 1 | - | - | 48 | 72.9 |
| 11 OE | - | - | - | - | - | 1 | - | 5 | - | 4 | 23 | - | 12 | - | 3 | - | 48 | 47.9 |
| 12 O | - | - | 3 | - | - | - | 1 | 1 | - | - | 5 | 37 | - | - | 1 | - | 48 | 77.1 |
| 13 UU | - | - | - | - | 1 | 1 | - | 8 | 2 | - | 6 | - | 27 | - | 3 | - | 48 | 56.3 |
| 14 UI | 5 | 4 | 1 | - | 9 | - | 1 | - | 2 | - | - | - | - | 26 | - | - | 48 | 54.2 |
| 15 U | - | - | - | - | - | 3 | - | 1 | 6 | - | 3 | 5 | 9 | 1 | 20 | - | 48 | 41.7 |
| Confusion | 5 | 8 | 19 | 14 | 12 | 7 | 5 | 38 | 25 | 9 | 22 | 13 | 37 | 13 | 22 | 0 | 249 | |