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NATO-NBVC 1200/2400 bps coder selection; results of TNO tests in phase 1

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S.J. van Wijngaarden, R.A. van Buuren and H.J.M. Steeneken

SUMMARY

Purpose: The NATO Ad-Hoc Working Group on Narrow Band Voice Coding (AHWG-NBVC) was tasked to select a new standard 1200 and 2400 bps vocoder for use throughout NATO. For this purpose, the AHWG has initiated a selection process, that is aimed at evaluating which of three candidates is the most suitable coder.
Method: During the first of three phases, speech intelligibility and speech quality measurements were carried out by three different test laboratories. TNO Human Factors was one of these laboratories; in phase 1, TNO-HF performed Consonant-Vowel-Consonant (CVC) tests for speech intelligibility, and Mean Opinion Score (MOS) tests for speech quality. All tests were carried out under four different acoustic noise conditions.
Results and conclusions: CVC and MOS tests yielded clear quantitative results, which have adequate statistical resolution to draw conclusions regarding differences in performance between coders. Since the candidate coders have been ‘blinded’, the identity of the coders is unknown to the authors of this report.

1 INTRODUCTION

In 1997, the NATO Ad-Hoc Working Group AC/322(SC/6-AHWG/3) on Narrow Band Voice Coding (AHWG-NBVC) was tasked to select a 1200/2400 bps voice coder for use throughout NATO. This selection was decided to take place through a competition between suitable existing voice coding algorithms. The winning coder will be described in STANAG 4591, which will be drafted by the AHWG-NBVC. This STANAG will hopefully find application in many (strategic and tactical) applications, contributing to end-to-end secure voice communications within and between NATO member nations.

The selection procedure consists of three phases. Phase 1 comprises speech intelligibility and speech quality tests. Phase 2 also features intelligibility and quality tests, in a greater number of conditions than phase 1. Some additional performance characteristics will also be tested in phase 2: intelligibility of whispered speech, language dependency and speaker recognisability. In phase 3 the coder performance in real-time will be evaluated, by carrying out communicability tests in several scenarios.

In phase 1, tests are carried out by three different test labs. In this report test results from the two different types of tests carried out by TNO Human Factors in phase 1 are given: CVC intelligibility results and MOS quality results.

2 CODERS, CONDITIONS AND SUBJECTS

There are three candidate coder pairs (each candidate can operate at both 1200 and 2400 bps) competing in phase 1. Combined with three references coders, a total of 9 coders is tested. The procedure for obtaining test stimuli for each of these 9 coders involves the activities of the host lab. For phases 1 and 2, the host lab is the NATO Command, Control and Consultation Agency (NC3A). The host lab was provided with unprocessed speech material. The only preparation of the speech material was to match the defined acoustic noise conditions. These conditions are given in Table I.

Table I Description of the noise conditions for phase 1.

Condition Nr.	Noise description	SNR (dB)
01	No noise	–
02	Speech babble	+6
03	Speech babble	+12
04	Modern office	+20

Speech material in the noise conditions given in Table I was obtained by mixing original ‘clean’ speech recordings electronically (or rather computationally) with noise samples. This mixing was carried out using TNO proprietary Matlab® scripts. All signal-to-noise ratios (SNR) were based on A-weighted levels, calculated using the SAM-SLM procedure (Van Velden, 1991).

The actual processing through the voice coders was done by the host lab. All processed speech material was returned to the test labs after being subjected to a blinding procedure. Test results as given in this report will be referred to as corresponding to the performance of coders 1 through 9. The actual mapping of the candidate and reference coders to these numbers is referred to as the ‘blinding key’; none of the employees or test subjects working at TNO Human Factors was given this key. Hence, the preparation, testing and evaluation of test results (including the writing of this report) could in no way be influenced by any bias towards any of the candidate coders.

All test subjects participating in CVC and MOS tests were university students of various disciplines, between 18 and 29 years of age. They were screened audiologically by means of pure-tone audiograms (125–8000 Hz). The rejection criterion was set at a best-ear maximum hearing loss of 25 dB at any frequency.

The coders, conditions and procedures used for processing and preparation of test conditions are described in more detail in the test plan (Tardelli *et al.*, 2000).

3 TEST METHODS

3.1 CVC method

The preferred method for measuring speech intelligibility of voice coders at TNO Human Factors is the CVC-method (Steeneken, Geurtsen & Agterhuis, 1990). This method uses simple Consonant-Vowel-Consonant nonsense words; such words, embedded in carrier phrases, were pre-recorded on DAT tape under good laboratory conditions (high quality microphones, no ambient noise). The recorded material consists of speech by eight speakers (4 males and 4 females). Sequences of CVC test-words were combined to obtain word lists of 51 words each. The source material was digitally transferred to a computer mass storage unit by means of an Ariel DAT-link digital audio interface. The speech was resampled to 8 kHz, and stored with 16 bit resolution. This material was mixed electronically with the appropriate acoustic noise files at the SNR levels given in table 1, and sent to the host lab on the designated media. After processing and blinding, the host lab returned the speech material to TNO Human Factors for evaluation.

The processed lists were all presented to a listening panel of 4 listeners, who were asked to respond with the CVC-words as they perceived them. Hence, each data point consists of 32 speaker-listener pairs (8 speakers times 4 listeners). When considering speaker gender as a separate variable, each data point consists of 16 speaker-listener pairs.

Before the test sessions, the subjects were trained. The actual responses of the subjects were given by typing the perceived CVC-words on computer terminals, connected to a central server computer.

As described in section 2, all coders were tested in various acoustic noise conditions. The presentation sequence was balanced for coders, conditions and speaker gender, to minimise the possibility of biased results due to learning effects.

All CVC word scores given in this report are so-called “equally balanced” CVC word scores. Since all phonemes have the same frequency of occurrence in the corpus of test stimuli, the CVC word score is by definition equally balanced. The mean equally balanced CVC word score is calculated for each condition, together with its estimated standard error (s.e.). This standard error is a measure for the accuracy of the mean CVC-wordscore. The standard error is related to the standard deviation according to

$$\text{s.e.} = \frac{s}{\sqrt{n}}$$

where s is the standard deviation, n the number of measuring points and s.e. the standard error. The standard deviation is a measure for the spread of the individual measurements; by using Student’s t-distribution, 95% confidence intervals (as required by the test plan) are easily computed from the standard errors.

The CVC test yields, besides the percentage of correctly responded CVC-words, separate scores for initial and final consonants and vowels. Moreover, confusion matrices are generated, which may be used to gain insight into the detailed performance of a particular coder.

3.2 MOS method

To evaluate speech quality, a choice must be made from a host of available test methods. One such method is known as the Mean Opinion Score (MOS) method. With this straightforward method, fragments of speech are presented to the subjects. After each presentation, subjects are asked to rate the quality of the fragment on a 5 point scale (1 indicating ‘bad’; 5 indicating ‘excellent’). Before the beginning of the actual test, subjects were give an operational definition of speech quality and trained using test stimuli varying widely in quality.

The stimuli were taken from a corpus of read sentences that was recorded at the same time as the CVC stimuli (Steeneken and Geurtsen, 1990), consisting of 65 Dutch everyday sentences, each 8 or 9 syllables in length, by the same 8 speakers as the CVC material.

Each MOS stimulus was a concatenation of two sentences, separated by a silence of approximately one second. After presentation of both sentences, the subjects were prompted by means of a short 1 kHz tone (duration 250 ms) to enter their response on a computer terminal. On this terminal, only the numerical keys 1-5 were activated. After a 3 second response period (within which subjects were free to change their response) the response was stored by a central server computer.

To enable a more or less test-independent interpretation of MOS responses, a calibration system is needed. The subjects' opinion on a stimulus is much influenced by the context in which it is presented; a calibration system provides a standardised context.

The calibration system used in this case is the MNRU (Modulated Noise Reference Unit, ITU-T Recommendation P.810) procedure. This procedure adds a controlled amount of speech-correlated noise at a chosen SNR, usually given the unit dBQ. The MNRU stimuli provide the subject with a standardised context of calibration stimuli having a spread in quality that should cover the complete 5-point MOS scale. For the NBVC phase 1 MOS test, 8 MNRU conditions were included (5–40 dBQ). Unprocessed 'clean' speech stimuli were also included in the presentation schedule.

A total of 16 subjects participated, 4 subjects at a time. All subjects were presented with 320 stimuli (9 coders * 4 conditions * 8 speakers gives 288 test stimuli; 8 MNRU and 1 'clean' stimulus * 8 speakers gives 72 stimuli). Each measuring point is based on 128 (8*16) speaker-listener pairs.

4 TEST RESULTS

4.1 CVC results to be used for the selection procedure

In Table II, mean equally-balanced CVC word scores and standard errors are given for all conditions. Each mean is based on the scores for 32 speaker-listener pairs.

Table II Mean equally-balanced CVC word scores (%) and standard errors, for coders 1-9 in conditions noise01-noise04 (N=32).

	Noise01		Noise02		Noise03		Noise04	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Coder 1	75.1	1.4	34.7	2.4	55.8	1.6	69.3	1.7
Coder 2	70.2	1.5	25.9	1.6	49.1	2.3	59.9	1.9
Coder 3	62.2	1.5	25.7	1.5	43.6	2.0	57.6	1.6
Coder 4	72.7	1.6	30.6	1.5	50.6	1.7	67.6	1.8
Coder 5	61.5	2.1	42.7	1.7	59.9	2.2	67.5	2.3
Coder 6	59.1	1.6	25.2	1.6	40.5	1.5	55.8	1.6
Coder 7	67.5	1.3	31.4	1.6	51.3	1.7	66.3	1.7
Coder 8	54.4	1.8	18.6	1.3	38.8	1.5	49.5	1.5
Coder 9	75.0	1.6	37.6	1.8	57.0	2.0	69.7	2.2

The CVC word scores for the different coders form a consistent pattern across the various acoustic noise conditions. The single result that may perhaps be regarded as surprising, is the difference between the 'noise01' condition (no noise) and the other conditions for coder 5. For coder 5, the CVC word score in absence of noise is relatively low compared to the performance in the noise conditions. The score is in fact lower in absence of noise ('noise01') than in the most benign of the three noise environments ('noise04'). This is not only true for the averages across speakers and listeners given in Table II; consistent results are found for all 8 of the individual speakers. Close correspondence between the mean results given in Table II and the median results for these same conditions confirm that this is a systematic effect, not due to anomalies in the testing procedure.

A broad comparison between mean and median values (after calculating the median values corresponding to the means given in Table II) shows that the average difference between mean and median value is 0.7 percent-point; the highest absolute difference is 4.1 percent-point. This confirms that the distribution of results as given in Table II shows a satisfactory degree of regularity and symmetry.

4.2 MOS results to be used for the selection procedure

In Table III, mean MOS scores and standard errors are given for all test conditions. Each mean is based on the scores for 128 speaker-listener pairs.

Table III Mean MOS scores and standard errors, for coders 1-9 in conditions noise01-noise04 (N=128).

	Noise01		Noise02		Noise03		Noise04	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Coder 1	3.66	0.07	1.80	0.07	2.45	0.08	2.97	0.07
Coder 2	3.28	0.08	1.50	0.06	2.09	0.06	2.44	0.07
Coder 3	2.87	0.07	1.11	0.03	1.76	0.06	2.58	0.06
Coder 4	3.45	0.06	1.63	0.06	2.35	0.08	2.53	0.07
Coder 5	2.40	0.07	1.76	0.07	2.09	0.07	2.09	0.07
Coder 6	2.59	0.07	1.23	0.04	1.56	0.05	1.94	0.06
Coder 7	3.27	0.07	1.46	0.05	1.64	0.06	2.20	0.07
Coder 8	2.19	0.07	1.13	0.03	1.50	0.06	1.69	0.06
Coder 9	3.45	0.07	1.70	0.07	2.34	0.06	2.83	0.06

The responses given in the MNRU calibration conditions can be used to verify the validity of the test. The MNRU responses should ideally cover the full MOS scale, and a monotonous relation between MNRU SNR (in dBQ) and the MOS score should be observed. The relation between MNRU SNR and mean MOS score (128 speaker-listener pairs per measuring point) is given in Figure 1.

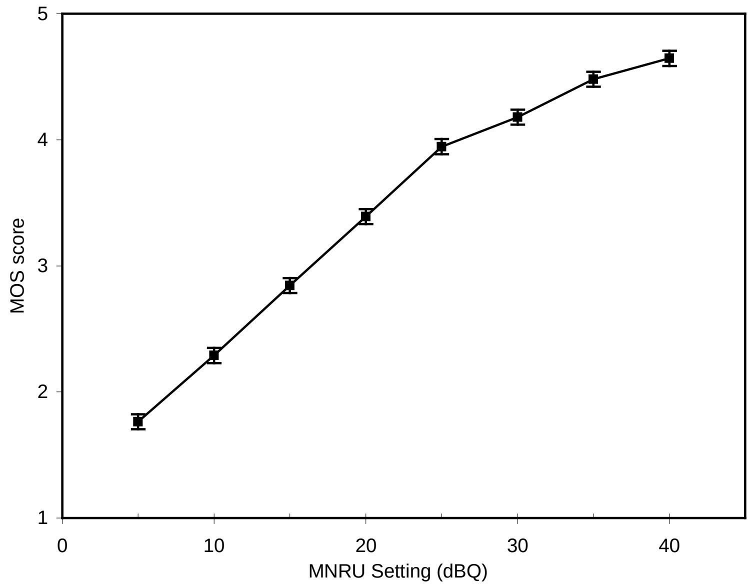

Fig. 1 Relation between MNRU SNR (dBQ) and mean MOS score. The error bars indicate the standard error (128 speaker-listener pairs per measuring point).

There is a noticeable ‘floor-effect’ in the MNRU-curve: since there are relatively many heavily distorted speech samples among the test conditions, the lowest dBQ-condition (5 dBQ) does not completely approach a MOS score of 1. This is commonly observed when applying MOS tests to narrow band voice coders.

4.3 Additional CVC and MOS results (informative)

Speaker gender is quite often an important variable for coder performance. In Table IV, mean equally-balanced CVC word scores and standard errors are given for male speakers and female speakers separately.

Table IV Mean equally-balanced CVC word scores (%) for male and female speakers separately, for coders 1–9 in conditions noise01-noise04. The average standard error corresponding to the mean values in this table is 2.1 (N=16).

	Noise01		Noise02		Noise03		Noise04	
	Male	Female	Male	Female	Male	Female	Male	Female
Coder 1	79.5	70.6	43.4	26.1	60.1	51.5	72.4	66.2
Coder 2	73.0	67.3	33.3	18.5	58.0	40.3	65.7	54.0
Coder 3	68.0	56.4	29.4	21.9	48.8	38.4	59.8	55.4
Coder 4	77.4	67.9	34.3	27.0	52.7	48.5	71.2	64.0
Coder 5	69.9	53.2	47.7	37.6	66.1	53.8	74.9	60.0
Coder 6	58.4	59.7	30.8	19.7	43.9	37.1	59.6	52.0
Coder 7	70.2	64.8	36.4	26.4	57.1	45.5	73.4	59.2
Coder 8	59.4	49.3	20.7	16.4	42.0	35.5	53.4	45.6
Coder 9	81.9	68.1	40.1	35.2	63.3	50.6	75.1	64.3

In Table V a similar comparison between speaker genders is given for the MOS scores.

Table V MOS scores for male and female speakers separately, for coders 1–9 in conditions noise01-noise04. The average standard error corresponding to the mean values in this table is 0.09 (N=64).

	Noise01		Noise02		Noise03		Noise04	
	Male	Female	Male	Female	Male	Female	Male	Female
Coder 1	3.84	3.47	2.14	1.45	2.83	2.08	2.90	3.03
Coder 2	3.33	3.23	1.77	1.23	2.28	1.89	2.33	2.55
Coder 3	2.88	2.86	1.19	1.03	1.90	1.61	2.50	2.66
Coder 4	3.58	3.33	1.80	1.45	2.72	1.98	2.47	2.59
Coder 5	2.47	2.33	2.06	1.44	2.41	1.76	1.95	2.23
Coder 6	2.38	2.81	1.33	1.14	1.64	1.48	2.06	1.81
Coder 7	2.94	3.59	1.56	1.36	1.75	1.53	2.28	2.11
Coder 8	2.14	2.24	1.16	1.09	1.66	1.35	1.70	1.67
Coder 9	3.39	3.51	1.84	1.56	2.49	2.19	2.88	2.79

Tables IV and V clearly show that some coders perform more gender-dependently than others.

Generally, a fair degree of correspondence is observed between speech quality and speech intelligibility. This is illustrated by Figure 2, in which the MOS quality results from Table V are plotted against the CVC intelligibility results from Table IV. The overall correlation coefficient is R=0.89, which corresponds to 80% explained variance.

From the CVC responses, full confusion matrices may be calculated. In Appendix A such confusion matrices are given for all 9 coders, pooled across conditions. Separate matrices are given for initial consonants, vowels and final consonants.

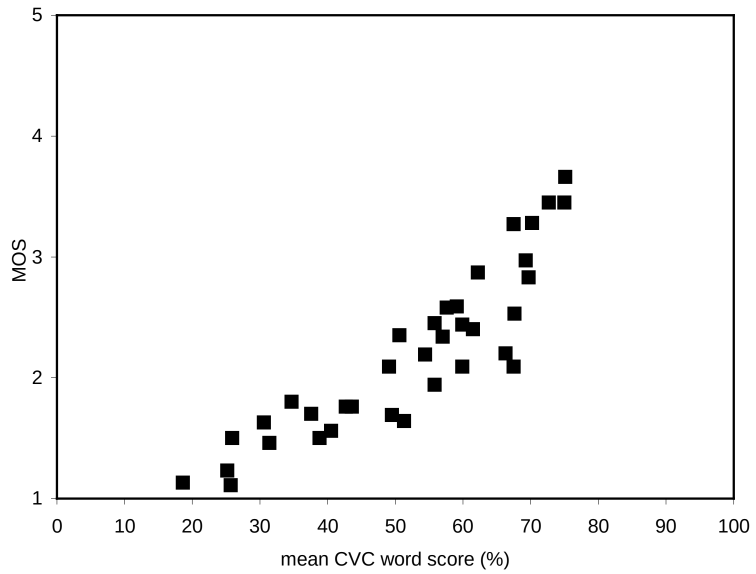

Fig. 2 Correlation between mean CVC-wordscores and MOS-scores. Each data point represents a coder-by-a-condition, for either all male or all female speakers (R=0.89).

5 CONCLUSIONS

CVC and MOS scores were obtained for 9 coders in the 4 acoustic noise conditions. The overall set of test scores appears as a coherent body of data; routine ‘health checks’ of the data uncovered no reasons to question the validity of the outcome.

The highest intelligibility in the absence of noise is offered by coders 1 and 9; in acoustic noise, coder 5 shows the highest CVC word score. According to MOS results, coder 1 offers the highest overall speech quality. Since the blinding key is unknown to the authors of this report, no further conclusions may be offered.

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Soesterberg, 18 January 2001

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APPENDIX A: Confusion matrices

The patterns of phone confusions that occur when using vocoders, will be a result of at least three different factors. First of all, there is a natural tendency of subjects to discriminate between some phoneme pairs better than between others. Secondly, the particular noise condition has an influence. Thirdly, and most importantly, there is the influence of the coder itself, which may represent some phonemes better than others. It is this particular effect which makes studying phoneme confusions worthwhile. The confusion matrices given in this annex are compiled from *all* responses for a given coder; they contain pooled results over all noise conditions. For each coder, three different matrices are given, corresponding to confusions of the initial consonant, the vowel, and the final consonant in each CVC word.
Table A.0.1 is an example of a confusion matrix, to explain the meaning of the values found in the tables of this appendix.

Table A.0.1 Example of a confusion matrix.

	p	t	k	??	Tot	%
p	288	14	25	5	384	75.0
t	19	312	33	7	384	81.3
k	19	13	330	3	384	85.9
conf	96	39	81	15		

The example table shows confusion between only three consonants: /p/, /t/, an /k/. Following regular conventions, each row contains all responses to a certain stimulus. In other words: the stimuli form the vertical axis of the matrix, the response categories the horizontal axis. Since the CVC-test is an open-response test, a fraction of the responses can not be classified according to the response categories. These are responses that do not meet the CVC word structure, or indicate phonemes that are not included in the CVC test, or perhaps no response at all. The column indicated by '??' lists all these irregular responses to each stimulus.
The column indicated by 'Tot' gives the total number of presentations for each stimulus; the column indicated by '%' gives the percentage of correct responses for each phone (stimulus). The bottom row ('conf') gives the number of confusions within each response category.
Some confusions are very common; examples are the /s/–/z/ and /f/–/v/ confusions. Similar phones are listed in the tables close to each other; for instance, the plosives form the top-left part of the confusion matrix of the tables for consonants. This implicates that confusions appearing close to the diagonal of the matrix should be expected to occur more frequently than confusions appearing away from the diagonal.

Table A.1.1 Confusion matrix of initial consonants for coder 1.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	288	14	25	5	1	23		4		12				1	5	1	4	1	384	75.0
t	19	312	33			9		3		4						1	3		384	81.3
k	19	13	330			4		1		6				1		2	5	3	384	85.9
b	6			212	9	3							1	8	144		1		384	55.2
d	7	7	1	15	284			1		1			1	6	32	19	5	5	384	74.0
f	12	2	12			260	4	47		35				1	3		6	2	384	67.7
s						6	357	1	16	1						1		2	384	93.0
v	16	1	4	6	1	113		176	1	12			3	2	31		17	1	384	45.8
z						1	38	6	305	2			1	6	1	15	9		384	79.4
χ	14	2	2			16	2	11		324					3	1	8	1	384	84.4
m			1								284	77	4		6	3	8	1	384	74.0
n											44	315	5	1	2	10	7		384	82.0
l					1						5	28	289	5	9	34	12	1	384	75.3
r			1	3				5	3	6	2	2	6	322	20	6	7	1	384	83.9
ʋ				11	2				3		7	8	1	8	321	6	13	4	384	83.6
j				1	4				2			1	1	3		369	3		384	96.1
h	3		2			1		3	1	12	4	1		1	5	6	343	2	384	89.3
conf	96	39	81	41	18	176	44	82	26	91	62	117	23	43	261	105	108	24		

Table A.1.2 Confusion matrix of vowels for coder 1.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	365	7	8				1							3			384	95.1
ɑu	2	309	66											5		2	384	80.5
ɑ	6	52	693		2		1				5	5		1	1	2	768	90.2
eː				332	4		5	6	33		1					3	384	86.5
ɛi				1	365		11	1	1					4		1	384	95.1
øː				7	1	303	2			4	1	1	5	2	56	2	384	78.9
ɛ		3	4	10	29	2	653	1	19		2	4	2	15	19	5	768	85.0
iː				1	3			356	6		10		7			1	384	92.7
ɪ				10		1	7	42	296		9	1	1		13	4	384	77.1
oː		8	3		1	1				287	10	71			1	2	384	74.7
uː										6	360	9	5		2	2	384	93.8
ɔ		2	9				1	1	1	26	20	320	3			1	384	83.3
yː								9	2		50	1	309	1	7	1	380	81.3
œy		6	1		5	2	2							370	2		388	95.4
ʉ						27		4	7		4	2	24	1	315		384	82.0
conf	8	78	91	29	45	33	30	64	69	36	112	94	47	32	101	26		

Table A.1.3 Confusion matrix of final consonants for coder 1.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	295	41	27	7		8	1				4	1	384	76.8
t	54	664	27	12	1	7	1				1	1	768	86.5
k	36	18	309	5		9	1		1	2	1	2	384	80.5
f	14	7	11	299	4	37	3	1	1	2	3	2	384	77.9
s	1	7	3	15	727	11				1	1	2	768	94.7
χ	6	9	7	31	1	322	1			1	6		384	83.9
m		1		1			521	63	172	6	3	1	768	67.8
ŋ							65	287	27	5			384	74.7
n							222	79	439	19	4	5	768	57.2
l	4	5				1	16	2	4	718	16	2	768	93.5
r	2		12	3		10	3	3	3	18	705	9	768	91.8
conf	117	88	87	74	6	83	313	148	208	54	39	25		

Table A.2.1 Confusion matrix of initial consonants for coder 2.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	282	17	27	4	3	30		5		2				1	3	2	7	1	384	73.4
t	55	238	41	2	6	15		4		6					2	3	10	2	384	62.0
k	42	5	287	2	1	9		9		13				3	1	3	9		384	74.7
b	7		2	162	14	1		1		4	4	4	1	8	171	2	3		384	42.2
d	2	3	6	31	230	2		4	1	1	2	1	1	13	71	10	5	1	384	59.9
f	20	7	12	1	1	242	3	51		34				1		3	9		384	63.0
s	2		3			10	345	2	15	6								1	384	89.8
v	18	2	4	4		101		170	3	21				6	23	6	23	3	384	44.3
z	1		1	1	3	2	31	4	298		1		2	3	6	30	1		384	77.6
χ	12		6			19	8	7	1	307				4	2		18		384	79.9
m											282	68	4	4	15	5	5	1	384	73.4
n		1									61	293	2	6	6	10	3	2	384	76.3
l	1						1	2			2	43	257	9	17	33	15	4	384	66.9
r				6	2	3		3	4	1	3	5	8	289	30	11	16	3	384	75.3
ʋ	1			13	1	1		3			6	4	5	16	316	6	11	1	384	82.3
j				1		1			2		1	4	4	8	9	349	4	1	384	90.9
h	8	4	2	2		4		3		6	2	4	3	2	8	14	320	2	384	83.3
conf	169	39	104	67	31	198	43	98	26	94	82	133	30	84	364	138	139	22		

Table A.2.2 Confusion matrix of vowels for coder 2.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	358	10	4		1									4		7	384	93.2
ɑu	5	322	40							5		1		10		1	384	83.9
ɑ	12	31	686				1			3		29		3	1	2	768	89.3
eː				336		1	2	18	25				1		1		384	87.5
ɛi	1			2	354		15				5	2		5			384	92.2
øː				4		320			3	1	1		6	6	40	3	384	83.3
ɛ		1	2	17	27	4	623	4	39		4	2	3	12	23	3	764	81.5
iː				2	2	2	1	338	10		11	2	10		3	3	384	88.0
ɪ				23	5	2	14	53	257		4	1	2		27		388	66.2
oː	2	9	1			1				303	15	50		2	1		384	78.9
uː						1	1	4		7	345	12	9		2	3	384	89.8
ɔ		3	8		3		1			24	17	324	1	1	1	1	384	84.4
yː						1		12	1		72		280		17	1	384	72.9
œy	4	15	1		14	11	5	3					1	329		1	384	85.7
ʉ			1	1		22	1	2	14		13	8	27		294	1	384	76.6
conf	24	69	57	49	52	45	41	96	92	40	142	107	60	43	116	26		

Table A.2.3 Confusion matrix of final consonants for coder 2.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	278	26	46	19	1	11	1				1	1	384	72.4
t	93	587	29	29	8	13				1	4	4	768	76.4
k	38	11	287	16		20				2	10		384	74.7
f	19	16	10	271	9	47	2	1	1	5	2	1	384	70.6
s	2	10		20	723	4				1	4	4	768	94.1
χ	5	4	3	27	6	323	3			2	11		384	84.1
m				1			525	51	183	7		1	768	68.4
ŋ	1						50	287	37	3	4	2	384	74.7
n	1					2	245	99	390	19	4	8	768	50.8
l	3	1	3	1		2	20	1	9	703	20	5	768	91.5
r	6	4	2	4	1	9	4	2	5	17	709	5	768	92.3
conf	168	72	93	117	25	108	325	154	235	57	60	31		

Table A.3.1 Confusion matrix of initial consonants for coder 3.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	281	21	43	4	2	6		6		7		1			4	2	5	2	384	73.2
t	27	284	47		3	7		1		5				2	1	2	5		384	74.0
k	23	11	325		1			1		8	1	1			1	6	6		384	84.6
b	10		5	135	16			2	1	4	8	1	3	4	172	5	18		384	35.2
d	8	16	5	16	213			5	2	1	3	1	5	11	50	33	12	3	384	55.5
f	29	6	15		1	226	11	36	2	38						1	18	1	384	58.9
s	1	1	1			16	339	3	13	8						1		1	384	88.3
v	25	8	5	7	3	94	2	152	3	19	1	1	1	4	29	8	20	2	384	39.6
z		1	2	1	1	1	36	3	292	7		2	4	2	4	24	2	2	384	76.0
χ	10	6	14			17	3	5		298	1			1	2	1	24	2	384	77.6
m			1								222	101	10	1	27	19	3		384	57.8
n						1		1	2		29	298	11	1	7	30	4		384	77.6
l									2		6	45	234	23	18	38	17	1	384	60.9
r		2	1	3	2	1		1	2	7	3	9	17	286	21	9	18	2	384	74.5
ʋ	4			6	3	2		11	1		4	4	12	11	296	17	13		384	77.1
j	1		2		1				2	1		3	6	5	6	346	11		384	90.1
h	7		9	1	1	5		2		13	7	7	5	9	27	36	252	3	384	65.6
conf	145	72	150	38	34	150	52	77	30	118	63	176	74	74	369	232	176	19		

Table A.3.2 Confusion matrix of vowels for coder 3.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	374		2	1		1								4	1	1	384	97.4
ɑu	3	324	48							2	3	2		2			384	84.4
ɑ	8	34	689				1			1		15		4	8	4	764	90.2
eː				331	3	4	3	12	28						1	2	384	86.2
ɛi	1			33	326		11	1	2					9		1	384	84.9
øː			1	7	1	292	2	1		3		9	3	7	53	1	380	76.8
ɛ	5	2	4	32	39	5	590	4	51	1		1	5	11	25	1	776	76.0
iː				10	1	2		313	15		10		28		5		384	81.5
ɪ			1	25	1	1	16	34	268		2	2	3		24	3	380	70.5
oː		6	5	1		4	1			285	8	66		2	8	2	388	73.5
uː	1	1	1			2	3	7	2	8	282	22	38		8	5	380	74.2
ɔ		3	20		1	1	2			34	19	299	2		1	2	384	77.9
yː			1	3		9		19	3		41	2	282	1	26	1	388	72.7
œy	3	6	3		23	18	4					1		322			380	84.7
ʉ	1			5		30	9		17	2	6	8	47		262	1	388	67.5
conf	22	52	86	117	69	77	52	78	118	51	89	128	126	40	160	24		

Table A.3.3 Confusion matrix of final consonants for coder 3.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	280	45	44	2		5	1	1	1	2	3		384	72.9
t	60	633	40	11	5	4	2	1	4	2	4	2	768	82.4
k	47	15	308	4		8	1	1					384	80.2
f	36	24	18	240	15	43		2		1	4	1	384	62.5
s	3	9		14	715	21		2	1		1	2	768	93.1
χ	15	11	22	18	14	292					10	2	384	76.0
m	2						517	53	174	16	6		768	67.3
ŋ	2		1			1	62	245	61	5	4	3	384	63.8
n						3	254	98	367	25	12	9	768	47.8
l	4		1	1			13	1	9	688	45	6	768	89.6
r	15		5	1		6	7	5	2	2	724	1	768	94.3
conf	184	104	131	51	34	91	340	164	252	53	89	26		

Table A.4.1 Confusion matrix of initial consonants for coder 4.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	290	11	31	4	1	16		5		5	1			1	3	2	13	1	384	75.5
t	26	310	34		9	1		1								2	1		384	80.7
k	11	9	337	4		2		1		7		2	4	1			5	1	384	87.8
b	11		4	149	21	1	1	3		2				6	169	5	8	4	384	38.8
d	5	15	8	6	279		1	1	1	3		1	2	5	37	19		1	384	72.7
f	20	10	14	2	1	243	2	48		27					2	1	11	3	384	63.3
s	2	2	2	1	1	12	337	5	3	9		1						1	376	89.6
v	21	6	14	7	3	82		164	2	17		1		1	34	5	24	3	384	42.7
z			1		1	4	20	7	311		2		2		10	30	3	1	392	79.3
χ	15	1	5			11	2	4		330					1	1	13	1	384	85.9
m					1	1					271	67	16	4	14	8	2		384	70.6
n						1			1		39	304	10	1	2	24	1	1	384	79.2
l			1		2						4	43	286	3	7	28	8	2	384	74.5
r		1	1		1			3		1	2	4	7	315	13	7	28	1	384	82.0
ʋ	1	1	1	15	1	4		2			5	7	12	11	306	4	14		384	79.7
j		2	3		3				2		1	1	2		7	357	6		384	93.0
h	11		3	3		2		7		7	6	3	2	11	9	17	301	2	384	78.4
conf	123	58	122	42	45	137	26	87	9	78	60	130	57	44	308	153	137	22		

Table A.4.2 Confusion matrix of vowels for coder 4.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	358	9	8								1			4			380	94.2
ɑu	1	325	49								1			3		1	380	85.5
ɑ	3	24	731				1	1	1		3	5				3	772	94.7
eː				337	4		2	6	33					1		1	384	87.8
ɛi	1			14	334	1	20		3		2	1		7		1	384	87.0
øː				6		318			2	2	1	6	7	5	42	3	392	81.1
ɛ		4	1	10	29	2	640	7	32	1			8	4	27	3	768	83.3
iː				1	1		2	347	9		6	2	14			2	384	90.4
ɪ				10	1	2	8	58	287				4		11	3	384	74.7
oː		9	5			5				275	7	80			3		384	71.6
uː		1		2		3	1	3	2	10	317	21	17		4	3	384	82.6
ɔ		6	9			1	3		1	34	18	303	1	1	4	3	384	78.9
yː				2	1	6		21	2	1	23	2	311		19	4	392	79.3
œy	5	7			4	1	5		1					352	1		376	93.6
ʉ			1			30	8	2	8		12	2	26	1	290		380	76.3
conf	10	60	73	45	40	51	50	98	94	48	74	119	77	26	111	27		

Table A.4.3 Confusion matrix of final consonants for coder 4.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	300	29	42	5		4	1					3	384	78.1
t	48	666	26	10	4	5	1			1	5	2	768	86.7
k	29	9	333			6				1	2	4	384	86.7
f	25	24	16	242	17	51	1			2	4	2	384	63.0
s	3	2	1	20	720	16					4	2	768	93.8
χ	12	8	26	20	6	301		1		2	5	3	384	78.4
m		2	1		2		502	63	173	16	10	3	772	65.0
ŋ						1	49	295	31	3	3	2	384	76.8
n	1				1	1	237	89	413	14	5	3	764	54.1
l	2		1	1			11	5	8	704	29	7	768	91.7
r	13	8	11	8	1	1	5		2	7	705	7	768	91.8
conf	133	82	124	64	31	85	305	158	214	46	67	38		

Table A.5.1 Confusion matrix of initial consonants for coder 5.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	307	38	23	1	4	6				2	1					1		1	384	79.9
t	22	327	28		3	1				1					1		1		384	85.2
k	22	7	344			1		1		7							2		384	89.6
b	14	2		281	33	1		3			2		2		46				384	73.2
d	1	18	2	32	314							1	2	1	3	10			384	81.8
f	80	19	21	1	1	203	1	40		9							5		380	53.4
s	5	21	2			27	317	7	1	4									384	82.6
v	27	8	10	12	3	68		184	6	4		1		3	47	2	12	1	388	47.4
z		4		2	13	6	32	6	278			1			12	29	1		384	72.4
χ	7	1	15			14		3		340					1		3		384	88.5
m											284	66	11		1	19	2	1	384	74.0
n											53	285	18			25	2	1	384	74.2
l					1	1					9	10	358		1	4			384	93.2
r	1											1	1	364	5	4	7	1	384	94.8
ʋ				14	5			1	1		7		13	7	312	15	9		384	81.3
j					5				2		3	2	1		7	362	1	1	384	94.3
h		5		1	2			1		1		3			4	2	365		384	95.1
conf	179	123	101	63	70	125	33	62	10	28	75	85	48	11	128	111	45	6		

Table A.5.2 Confusion matrix of vowels for coder 5.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	369	3	3		1									3		1	380	97.1
ɑu	3	336	35		2					3	1			4			384	87.5
ɑ	3	39	718			1	2					3		1		1	768	93.5
eː				334	4	2	3	3	41							1	388	86.1
ɛi				6	360		10		1					6		1	384	93.8
øː				12		328	1		1	2	2			4	33	1	384	85.4
ɛ			1	3	33		710	1	6			1		8	5		768	92.4
iː				6	1	1	1	348	6		3		18				384	90.6
ɪ				21		1	9	32	305		3	3	4		5	1	384	79.4
oː			2			2				330	8	42					384	85.9
uː				4	1	1		15	7	4	307	4	33		8		384	79.9
ɔ		4	2	3	1		2		1	32	6	331				2	384	86.2
yː						4	1	50	2		15		295	5	3	1	376	78.5
œy		6	1		6	5								369	1		388	95.1
ʉ				5		18	1		26		3	1	8		325	1	388	83.8
conf	6	52	44	60	49	35	30	101	91	41	41	54	63	31	55	10		

Table A.5.3 Confusion matrix of final consonants for coder 5.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	308	30	37	1		5	1					2	384	80.2
t	140	576	39	4	2	3	1					3	768	75.0
k	53	8	318	1		3						1	384	82.8
f	67	38	33	184	9	49			1	2		1	384	47.9
s	15	51	3	53	622	16	2				4	2	768	81.0
χ	24	3	18	9	2	319	2			2	5		384	83.1
m							602	15	139	11		1	768	78.4
ŋ							48	298	34	4			384	77.6
n							270	50	440	5	1	2	768	57.3
l		3					6		3	739	14	3	768	96.2
r	21	10	12	8		9	2			4	702		768	91.4
conf	320	143	142	76	13	85	332	65	177	28	24	15		

Table A.6.1 Confusion matrix of initial consonants for coder 6.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	227	24	21	3	1	80		17		5			1			1	4		384	59.1
t	38	278	20	1	11	17	5	5	5	3							1		384	72.4
k	22	14	302		1	11	2	1	2	18	1	1				1	5	3	384	78.6
b	12		2	168	14	11		17	1	1	7		2	8	133	3	4	1	384	43.8
d	2	16	5	16	245	4			7	4		1	6	3	49	27	2	1	388	63.1
f	17	5	10	1		283	6	39		17				1	1		4		384	73.7
s	1	5	3			4	353	2	7	7								2	384	91.9
v	7	9	8	9	13	128	2	109	5	14			1	7	59	3	7	3	384	28.4
z		2	2	4	18	5	56	5	226	5		1	1	10	6	42		1	384	58.9
χ	8	8	9			30	5	6	1	302					1		11	3	384	78.6
m						1					247	57	22	2	39	10	5	1	384	64.3
n					2				1		56	243	28	2	6	40	1	1	380	63.9
l				1	4				2		9	13	274	20	17	36	7	1	384	71.4
r	1	1	2		4	1		3		2	3	1	11	265	48	5	35	2	384	69.0
ʋ				18	8	2		2	2		9	2	8	17	283	13	20		384	73.7
j		1	3		11			2	3	1	6	4	2	5	16	319	9	2	384	83.1
h	8	2	1	3	4	9	1	6	2	27	3	2	12	14	21	28	238	3	384	62.0
conf	116	87	86	56	91	303	77	105	38	104	94	82	94	89	396	209	115	24		

Table A.6.2 Confusion matrix of vowels for coder 6.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	369	1	4											7		3	384	96.1
ɑu	10	305	57		1					4		2		8		1	388	78.6
ɑ	13	50	671		3		1	1		3	1	15		8		2	768	87.4
eː				303	6	4		16	49				2		1	3	384	78.9
ɛi	1		1	14	355	1	6						1	4		1	384	92.4
øː				1	1	324	2		3		2	1	3	4	40	3	384	84.4
ɛ	3	1		13	40	20	585	4	38			6	11	13	31	3	768	76.2
iː				6	1	1		322	20	1	9		20		3	1	384	83.9
ɪ				40	1	6	11	28	281		1	1	2		11	2	384	73.2
oː		11	7	2		4		3		240	5	95		2	8	3	380	63.2
uː		2		1		8	2	24	2	7	283	14	29		12		384	73.7
ɔ	1	2	11	2		4	3	3	1	34	34	280		1	6	2	384	72.9
yː						26		10	6		13		297	1	31		384	77.3
œy	7	4	2		12	1	5							353			384	91.9
ʉ				1	1	42	4	1	15	3	1	3	53	1	257	2	384	66.9
conf	35	71	82	80	66	117	34	90	134	52	66	137	121	49	143	26		

Table A.6.3 Confusion matrix of final consonants for coder 6.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	256	48	21	42		12		2			2	1	384	66.7
t	53	587	32	56	9	17		1		4	6	3	768	76.4
k	38	36	259	21	2	17	1			4	5	1	384	67.4
f	13	19	8	289	18	28				1	4	4	384	75.3
s	3	8	1	22	722	7	1				1	3	768	94.0
χ	8	17	9	39	20	270	3		1	7	9	1	384	70.3
m		3					569	61	108	10	14	3	768	74.1
ŋ	2			1		1	83	232	42	9	14		384	60.4
n	1			2	1	1	319	70	345	8	17	4	768	44.9
l	3		1	1		2	28	2	9	679	40	3	768	88.4
r	6	6	5	14	5	20	7	2	3	12	684	4	768	89.1
conf	127	137	77	198	55	105	442	138	163	55	112	27		

Table A.7.1 Confusion matrix of initial consonants for coder 7.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	276	20	29	8	1	27		7		6			2		1	1	4	2	384	71.9
t	26	298	36		4	13	1	1		1				1		1	1	1	384	77.6
k	32	11	327			8		1		3							1	1	384	85.2
b	8		4	207	20	2		2		4			3	5	121	6	1	1	384	53.9
d	5	11	5	23	299	1		2	1				1		21	15			384	77.9
f	27	10	11		1	277	5	33		15				1		1	2	1	384	72.1
s	1	8	2			10	343	3	8	3						1		1	380	90.3
v	14	3	6	7		129		114	5	18			1	1	69	2	10	5	384	29.7
z				1	5	2	21	5	280	4			5	3	20	34	4		384	72.9
χ	18	4	15			27	9	2	2	307							3	1	388	79.1
m											292	52	8	1	21	6	3	1	384	76.0
n	2										36	289	24	5	8	20			384	75.3
l					1						7	15	305	10	14	25	7		384	79.4
r	1	1	1	4	2	1		2		3			8	318	26	5	11	1	384	82.8
ʋ			1	15	5			5		1	2		2	10	323	8	11	1	384	84.1
j					5				5	1	4	6	11	1	6	342	3		384	89.1
h	5		8	3	4	5		8		8	3	4	3	9	21	15	288	12	396	72.7
conf	139	68	118	61	48	225	36	71	21	67	52	77	68	47	328	140	61	28		

Table A.7.2 Confusion matrix of vowels for coder 7.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	369	2	7	1		1								4			384	96.1
ɑu	1	352	29			1				1				1		3	388	90.7
ɑ	5	53	698		1		2			2		4		2		1	768	90.9
eː				322		2	4	14	37						4	1	384	83.9
ɛi				9	355		7	2				1		10			384	92.4
øː				1		307	1	2		2	1	1	9	2	54		380	80.8
ɛ		1	1	7	19	4	668		28	1		3	9	10	15	2	768	87.0
iː				9		1		330	14		5		18	2	2	3	384	85.9
ɪ				20		1	7	57	272				11		14	2	384	70.8
oː		9	1	2		2	1		2	280	11	73			1	2	384	72.9
uː			1	1		6			1	6	320	6	32		5	2	380	84.2
ɔ			9	1	1	1	11	1	5	43	14	299		1	1	1	388	77.1
yː				2		6		14	2		10	1	334		14	1	384	87.0
œy	4	6			3	6	5							355		1	380	93.4
ʉ						38		1	9		2	1	34	1	300	2	388	77.3
conf	10	71	48	53	24	69	38	91	98	55	43	90	113	33	110	21		

Table A.7.3 Confusion matrix of final consonants for coder 7.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	279	26	39	23		10	1			2	2	2	384	72.7
t	74	596	48	30	3	11				1	2	3	768	77.6
k	41	24	297	7		7	1		1		6		384	77.3
f	21	19	8	290	10	29	1			1	3	2	384	75.5
s	2	8	5	28	709	12	1				2	1	768	92.3
χ	10	13	13	33	10	292	1		1	1	9	1	384	76.0
m				1		1	586	37	131	3	7	2	768	76.3
ŋ	2		1				79	260	35	1	5	1	384	67.7
n	2			1			275	72	397	10	4	3	764	52.0
l	5	1	2			2	21		7	695	36	3	772	90.0
r	5	5	11	6	2	17	1	2	4	14	698	3	768	90.9
conf	162	96	127	129	25	89	381	111	179	33	76	21		

Table A.8.1 Confusion matrix of initial consonants for coder 8.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	275	29	22	6	1	31	1			5					11		2	1	384	71.6
t	51	249	45	1	7	7	2	2		7			1			4	2	6	384	64.8
k	58	26	286	2		2	1			6						2	1		384	74.5
b	24	4	2	106	9	4		5		1	13	3	1	7	194	4	5	2	384	27.6
d	10	22	7	16	235	2		1				1	6	7	47	23	5	2	384	61.2
f	56	13	11			257		20	2	11			1		5		3	9	388	66.2
s			4			12	357	2	1	3								1	380	93.9
v	19	8	8	5	7	147	1	98	6	5		2	2	11	48	2	6	1	376	26.1
z	2	1	1			2	65	4	269	4		1	4	6	1	21	1	2	384	70.1
χ	43	2	30	1	2	74	10	7		201			1	3	3	1	5	5	388	51.8
m	2		2	1	1			1	1		272	37	11	5	36	9	4	2	384	70.8
n	1		3								75	246	16	2	10	27	1	3	384	64.1
l		5	2	5	5	1		1	3	1	6	22	249	14	19	42	8	1	384	64.8
r	8	3	1	6	4	3	1	5	3	7	5	9	14	242	37	11	24	1	384	63.0
ʋ	11	1	3	6	6	4				1	13	1	5	15	308	5	8	1	388	79.4
j	3	1	2	4	2				3		4	4	3	4	16	327	9	2	384	85.2
h	17		3	5	5	23		13		20	8	3	5	5	39	19	215	4	384	56.0
conf	305	115	146	58	49	312	81	61	19	71	124	83	70	79	466	170	84	43		

Table A.8.2 Confusion matrix of vowels for coder 8.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	323	10	24	2			5		1	1	3		1	8		6	384	84.1
ɑu	2	289	67		1	1				12		4		6	1	1	384	75.3
ɑ	11	36	646			3			1	6	10	34	1	5	5	10	768	84.1
eː				334	1	3	2	1	36							3	380	87.9
ɛi	4			44	310		15	2	4					4		1	384	80.7
øː				9	2	298			2	1	1	3	11	2	61	2	392	76.0
ɛ	1			17	38	3	598	6	55		2		11	7	26	4	768	77.9
iː				16	3	2		289	51		4		12		5	2	384	75.3
ɪ				35	2	2	12	30	278		1		7		12	5	384	72.4
oː		11	3	2		7	2			270	8	74		3	2	2	384	70.3
uː		1		4		9		8	3	13	274	18	40		11	3	384	71.4
ɔ		4	20			3	1	1	5	35	37	271	1		4	2	384	70.6
yː				2		18		14	3		24	1	285		36	1	384	74.2
œy	4	7	1		11	47	12	2					1	283	8		376	75.3
ʉ				3		43	6	1	13	2	7	6	26	1	276	4	388	71.1
conf	22	69	115	134	58	141	55	65	174	70	97	140	111	36	171	46		

Table A.8.3 Confusion matrix of final consonants for coder 8.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	256	55	61	4		2	1			1	2	2	384	66.7
t	87	575	59	19	9	3	1		1		4	10	768	74.9
k	45	23	297	5	1	8	1		1	1		2	384	77.3
f	38	26	31	239	19	25				1	4	1	384	62.2
s		1		38	716	9						4	768	93.2
χ	27	25	27	71	19	206	1				7	1	384	53.6
m	5	3	4	2		1	524	81	121	10	4	5	760	68.9
ŋ		1	4	1			84	254	29	2	4	5	384	66.1
n	1	7	4	1		1	302	93	326	26	13	2	776	42.0
l	5	2	4	1		2	16	6	4	669	52	7	768	87.1
r	16	12	21	24	1	18	9	7	5	9	635	11	768	82.7
conf	224	155	215	166	49	69	415	187	161	50	90	50		

Table A.9.1 Confusion matrix of initial consonants for coder 9.

	p	t	k	b	d	f	s	v	z	χ	m	n	l	r	ʋ	j	h	??	Tot	%
p	285	27	39		1	12		6		11						1	2		384	74.2
t	49	272	33		6	10		1		6				1	1	2	1	2	384	70.8
k	20	9	340	2	1	4		2		7						1		2	388	87.6
b	19		3	243	19			1		1	5			2	88	1	2		384	63.3
d	1	5	4	28	287			1	3	1				7	29	15	3		384	74.7
f	32	6	20	1		249		32		33				1	1	2	3		380	65.5
s	2	1				1	355		17	4									380	93.4
v	27	4	5	7	8	95		167	8	15				9	31	7	5		388	43.0
z		1				2	22		324	2				4	5	24	2	2	388	83.5
χ	6	1	15		1	10	3			336							6	2	380	88.4
m											295	67	5		9	2	2		380	77.6
n											34	318	19	1	4	12			388	82.0
l				2	2						8	21	307	11	11	19	3		384	79.9
r	3	2		8				4		2				341	12	2	8	2	384	88.8
ʋ	1		4	10	4			1	1		4	1	7	8	323	12	6	2	384	84.1
j					3		1		1	1	2	3	6	1	5	360	1		384	93.8
h		3	7	4	1	2		1		6	3	2		4	8	14	329		384	85.7
conf	160	59	130	62	46	136	26	49	30	89	56	94	37	49	204	114	44	12		

Table A.9.2 Confusion matrix of vowels for coder 9.

	aː	ɑu	ɑ	eː	ɛi	øː	ɛ	iː	ɪ	oː	uː	ɔ	yː	œy	ʉ	??	Tot	%
aː	362	10	9											2		1	384	94.3
ɑu	4	331	32		1		1			2	1	1		7			380	87.1
ɑ	5	33	721				2			1		1		3	1	1	768	93.9
eː				354			1	2	27								384	92.2
ɛi				4	366		8							6			384	95.3
øː				4		323	1	1	1	6	1		8	1	32	2	380	85.0
ɛ	1		3	6	20	3	663	4	39	1	3	5	4	6	6	4	768	86.3
iː					2			356	1		4		21				384	92.7
ɪ				6		1	5	26	322		3		3		17	1	384	83.9
oː		9	3	1	2	1				323	5	42			2		388	83.2
uː						2	2	3		9	320	8	32		4		380	84.2
ɔ	1	2	5	1		3	2			25	6	334			3	2	384	87.0
yː						3		15			31		328		8	3	388	84.5
œy	5	7	2		23	3	4						4	339	1		388	87.4
ʉ			1			25	2	2	18	1	3	7	30		295		384	76.8
conf	16	61	55	22	48	41	28	53	86	45	57	64	102	25	74	14		

Table A.9.3 Confusion matrix of final consonants for coder 9.

	p	t	k	f	s	χ	m	ŋ	n	l	r	??	Tot	%
p	312	17	39			10	1			1	3	1	384	81.3
t	69	625	47	4	3	12	1				3	4	768	81.4
k	43	21	309	1		8			1			1	384	80.5
f	25	30	17	246		50	3		2	6	3	2	384	64.1
s		5		8	745	7					1	2	768	97.0
χ	7	8	23	7	8	320	2		3	2	4		384	83.3
m						1	565	63	133	3	3		768	73.6
ŋ							42	309	24	6	1	2	384	80.5
n					1		238	86	429	11	2	1	768	55.9
l	1		3		1		13	2	4	723	19	2	768	94.1
r	6	1	4	7		5	1		3	22	718	1	768	93.5
conf	151	82	133	27	13	93	301	151	170	51	39	16		