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Kristin Hedges

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**Phoneme Analysis of Cochlear Implant
Recipients' Responses to CNC Words using the
MPEAK and SPEAK Speech Coding Strategies
of the Nucleus Cochlear Implant System**

Kristin Hedges, M.S.

Independent Study completed May, 1995

Supervisor: Margaret W. Skinner, Ph.D.

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Introduction

The use of an intracochlear, multielectrode cochlear implant now allows postlinguistically deaf adults, with a useful surviving population of peripheral auditory neurons, to receive hearing sensations when the surviving nerve fibers are electrically stimulated. These implant users are able to recognize a substantial number of words in sentences spoken in everyday life. A field trial was conducted in 1993 with 63 postlinguistically deaf adults from 4 English speaking countries. The subjects' performance was evaluated using the MPEAK speech coding strategy with the Mini Speech Processor MSP, versus the SPEAK speech coding strategy with the Spectra 22 processor of the Nucleus 22 Channel Cochlear Implant System (Skinner et al, 1994). The subjects had previous experience using MPEAK but were using the SPEAK coding strategy for the first time.

A portion of the trial was conducted at Washington University School of Medicine, where nine adult subjects participated. Their data, collected during the field study, was available for further analysis. It was of interest to understand how the implant users perceived individual speech sounds using MPEAK compared to the SPEAK speech coding strategy. Historically, human recognition of individual speech sounds has been analyzed using nonsense syllables. In their classic study, Miller and Nicely (1955) examined 16 initial consonants spoken in 200 nonsense syllables. The results were presented in the form of confusion matrices. Articulatory analysis of the 16 consonants along with the data from the confusion matrices allowed perceptual confusions among the consonants to be analyzed as a function of low-pass and high-pass frequency cut off as well as signal-to-noise ratio. Another study looked at hearing impaired subjects' perceptual confusions among consonants also using confusion matrices (Wang and Bilger, 1973). The stimuli were 4 sets of CV and VC nonsense syllables. The use of confusion matrices allowed distinctive features of speech to be analyzed, and the percentage of the information transmitted relative to each feature to be assessed. With this type of analysis, the relative importance of specific features of speech as a function of listening condition can be determined. In a subsequent analysis of nine subjects' data

obtained during the field study (Skinner et al, 1994), subject's responses to vowels and consonants were analyzed individually, and the data were compared with acoustic and electrical analyses of the speech in nonsense syllables (Skinner et al, 1995, a & b).

Although the methods mentioned previously are highly effective for understanding how individuals perceive speech sounds in a number of listening situations, vowels and consonants presented in nonsense syllables are not as representative of the acoustic cues in true running speech as if actual words are used in the evaluation. For this reason, the nine subjects' responses to single-syllable words using the two speech coding strategies were examined to determine which features of 26 consonants and 17 vowels were important for understanding with each of the coding strategies. The MPEAK speech coding strategy is available with the MSP (Mini Speech Processor) and the SPEAK speech coding strategy is used with the Spectra 22 speech processor. Results were presented in the form of confusion matrices and an Analysis of Variance (ANOVA) was performed to determine statistically significant differences in performance.

Methods

Subjects

Previously collected data from nine postlinguistically deaf adults evaluated at Washington University School of Medicine were examined. Biographical information on each subject, including cause of deafness, number of years of deafness, and depth of electrode insertion for each implant recipient, is given in Table 1. All subjects, except subject 6, used a bipolar stimulation mode. Subject 6 used a common ground mode of stimulation. A bipolar +1 mode of stimulation was used by subjects 2, 3, 5, 7, and 9. A bipolar +2 mode of stimulation was used by subject 8, and a bipolar +3 mode was used by subjects 1 and 4. Active and return electrodes for all the bipolar modes of stimulation were separated by 1.5, 2.25, and 3.0 mm, respectively. The MPEAK strategy had been used by all subjects for at least 32 months prior to data collection.

Table 1. Subject Biographical Information

<u>Subject</u>	<u>Sex</u>	<u>Etiology</u>	<u># of Years of Profound Deafness</u>	<u>Age at Implantation (years)</u>	<u>Depth of Electrode Insertion</u>	<u>Months of MPEAK Use</u>
1	F	Luetic Deafness	4	60	20	46
2	M	Auto-Immune Disease	4	44	23	46
3	F	Luetic Deafness	2	52	25	46
4	M	Otosclerosis	10	61	25	46
5	M	Acoustic Trauma (explosion) Progressive Hearing loss	4	61	25	46
6	F	Progressive Hearing Loss Following Maternal Rubella	22	45	25	46
7	M	Severe Otic and Brainstem Trauma; Temporal Bone Fracture	17	38	21	39
8	F	Unknown	0.25	35	21	35
9	F	Progressive Hearing Loss Following Meningitis	9	26	20	32

Speech Processor and Coding Strategies

Two types of processors were used in this evaluation. The Mini Speech Processor (MSP) is used with the MPEAK coding strategy. The MSP contains a custom monolithic chip with two filters (280-1000 Hz; 800-4000 Hz) to estimate the F1 and F2 formant frequencies and amplitude, as well as, three high frequency filters to estimate the amplitudes of incoming acoustic signals. The three high frequency bandwidths are 2 kHz-2.8 kHz, 2.8 kHz-4 kHz, and 4 kHz-6 kHz.

The second speech coding strategy, SPEAK, is used with the Spectra 22 processor. The Spectra 22 consists of a spectrum analyzer containing a maximum of 20 bandpass filters,

rectifiers, and lowpass filters. The bandpass filter frequencies are spaced linearly from the lowest frequency to about 1.6 kHz, and then logarithmically to the highest frequency. The lowest frequency analyzed is 75 Hz and the highest frequency is 10,823 Hz; the maximum bandwidth depends on the number of active electrodes, and the frequency boundary assignment table chosen. For the field trial, the maximum bandwidth for 20 electrodes was 150 to 10,823 Hz.

MPEAK uses a feature extraction strategy to code incoming acoustic signals. Feature extraction involves the estimation of the frequencies of the fundamental frequency (F0), the first formant (F1), and the second formant (F2). The amplitudes of F1 and F2 are also estimated. F1 has a frequency range of 280-1000 Hz, is divided into equal linear steps, and assigned to the apical third of active electrodes in the electrode array. F2 has a frequency range of 800-4000 Hz, is divided into equal logarithmic steps, and assigned to the basal two-thirds of active electrodes in the electrode array. In addition, the amplitude in each of three bands is estimated in the frequency ranges - 2.0 to 2.8 kHz (Band 3), 2.8 to 4 kHz (Band 4), and 4.0-6.0 kHz (Band 5). Four electrode pairs are periodically stimulated with selection depending on the acoustic features extracted from the incoming signal. The rate of stimulation is determined by F0 for periodic sounds; for aperiodic sounds, a random rate around 250 Hz is used. Place of stimulation along the electrode array is determined by the F1 and F2 frequencies as well as the sound energy detected by the three high-frequency filter bands (Skinner et al, 1991).

The SPEAK strategy differs from MPEAK in that SPEAK uses a filterbank strategy for analyzing the incoming acoustic signal. With a maximum of 20 bandpass filters, the spectrum of the incoming signal is approximated. Each of the 20 filters is assigned tonotopically to the user's electrodes. The lowest frequency band is assigned to the most apical electrode. The entire spectrum of the incoming signal is examined and the portions of the signal with the largest amplitudes are selected in real time. The portions of the signal that are selected are called the spectral maxima of the signal. For vowels, nasals, glides, and

liquids, the spectral maxima represent the formants of speech. From 1 to 10 of the largest outputs (maxima) of the 20 filters are used to stimulate the cochlea on a place basis at an adaptive rate. During each stimulus period, an average of 6 electrodes are activated instead of 4 as with the MPEAK strategy (Skinner et al, 1994). Better spectral detail is provided with SPEAK, in part, because of the stimulation of adjacent electrodes instead of estimation of just one electrode for each formant, which is used with MPEAK.

Speech Material

Test materials consisted of recorded CNC word lists (Peterson and Lehiste, 1962) presented at 70 dB SPL. There are 10 lists, each containing 50 words, spoken by a male talker (Cochlear Corporation). Each list contains approximately the same set of phonemes with an equal proportion of initial consonants, medial vowels, and final consonants. All words are monosyllables; the incidence of each phoneme in each list reflects that of spoken American English. For the field trial, list 1 was used for practice; eight of the other nine lists were used for testing, four for each speech coding strategy.

Test Equipment/Environment

Each subject was presented recorded CNC word lists via a cassette player (Tascam, Model 112) in a double-walled sound booth (IAC, model 1204-A; 254 cm x 264 cm x 198 cm). Subjects were seated at 0° azimuth, 1.5 meters in front of the loudspeaker. The words were presented through a Urei loudspeaker (model 809) using a PDP-11/23+ computer which was interfaced, along with the cassette player, to a custom built audiological console. Subject responses were written on a test sheet for subsequent scoring. The sound pressure level of the acoustic stimuli was measured with a sound level meter; the microphone was placed where the subject's head would be during testing.

Procedures

Speech Processor Settings

At the time of data collection, the MPEAK speech processor program for each subject was adjusted. A maximum of 22 electrodes may be utilized with MPEAK. For each active electrode, the subject's thresholds and maximum acceptable loudness levels were programmed according to three criteria. First, with the sensitivity control set at it's optimum midrange setting, everyday sounds were made as natural sounding and comfortably loud as possible. Second, loud sounds were adjusted so they were not perceived as too loud. Third, soft speech was made audible. Figure 1 shows each subject's thresholds, maximum acceptable loudness levels, Q value, and base levels used in the MPEAK speech processor program.

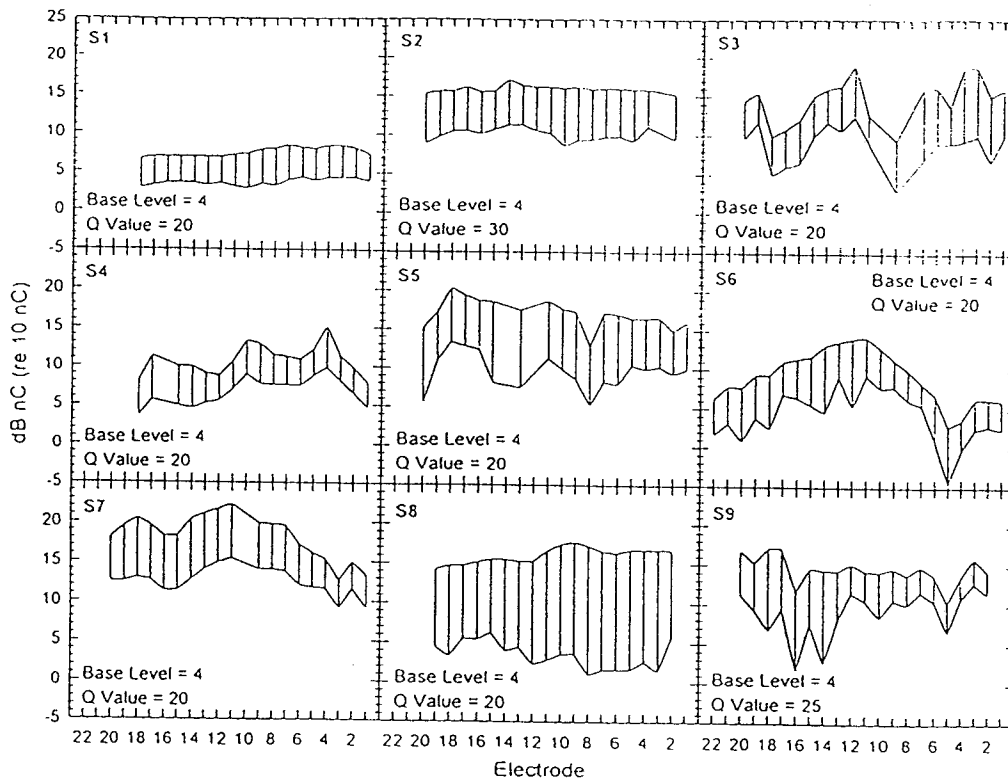


Figure 1. Electrical dynamic range (dB re 10 nC) for each electrode as specified in each subject's MPEAK program for the Mini Speech Processor; the dynamic range is the area between threshold (lower curve in each panel) and maximum acceptable loudness level (upper curve in each panel). Base level and Q value are also shown. Electrodes 22 through 1 represent pitch percepts from low to high.

The SPEAK speech coding strategy allows a maximum of 20 active electrodes to be used. Originally, the same thresholds and maximum acceptable loudness levels that were used with MPEAK were also used when programming in SPEAK. However, some subjects found that when an average of six, instead of four, electrodes are stimulated, their loudness perception of sound increased. For this reason, some of the subjects' loudness levels as well as thresholds were modified.

For subjects 1, 3, 4, and 8, the gain on all bandpass filters was set at 8. The remaining subjects had a reduced gain setting of 6 assigned to the four most apical electrodes to reduce the loudness of low-pitched sound. For high-frequency sound to be acceptable to subject 6, gain was reduced to 6 on the four most basal electrodes. Subject 7 also required a reduction in the gain on the three most basal electrodes to 6 for high-frequency sound to be acceptable.

Table 2 lists the upper frequency (Hz) of bandpasses assigned to active electrodes for each strategy. The largest difference in frequency boundary assignment between strategies was for subjects 5 and 6. In MPEAK, they both had seven electrodes assigned to the F1 frequency region from 280Hz-1kHz. In SPEAK, they each had four electrodes assigned to 150-950Hz.

For data collection, subjects wore the sensitivity control of their speech processor set at a comfortable level according to use in everyday life. Speech processors were always set for normal function, instead of noise suppression.

Experimental Design

To evaluate possible effects of learning, a reverse, replicated (A_1, B_1, A_2, B_2) design was used. Also, one CNC word list was presented during each of two test sessions. These test sessions were one week apart for each of the four time periods.

The first time period (A_1) was four weeks. Subjects used the MPEAK strategy during this period. It was a shorter period than the second (B_1) during which the subjects first used SPEAK. Each subject was given seven weeks to listen with the SPEAK strategy. The

Table 2. Upper frequency (Hz) of bandpass assigned to each subject's electrodes for the MPEAK (M) and SPEAK (S) speech coding strategies.

	Subjects																	
	1		2		3		4		5		6		7		8		9	
	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
22	-	-	-	-	-	-	-	-	-	-	400	350	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	485	550	-	-	-	-	-	-
20	-	-	400	350	400	350	-	-	300	350	571	750	400	350	-	-	400	350
19	-	-	520	550	520	550	-	-	416	550	657	950	500	550	400	350	500	550
18	400	350	640	750	640	750	400	350	533	750	742	1150	600	750	520	550	600	750
17	520	550	760	950	760	950	522	550	650	950	828	1350	700	950	640	750	700	950
16	640	750	880	1150	880	1150	-	-	766	1150	914	1550	800	1150	760	950	800	1150
15	760	950	1000	1350	1000	1350	644	750	883	1350	1000	1768	900	1350	880	1150	900	1350
14	880	1150	1122	1550	1122	1550	767	950	-	-	1104	2031	1000	1550	1000	1350	1000	1550
13	1000	1350	1259	1768	1259	1768	889	1150	1000	1550	1219	2333	1122	1768	1122	1550	1122	1768
12	1122	1550	1414	2031	1414	2031	1011	1350	-	-	1345	2680	1259	2031	1259	1768	1259	2031
11	1259	1768	1587	2333	1587	2333	1134	1550	1134	1768	1485	3079	1414	2333	1414	2031	1414	2333
10	1414	2031	1781	2680	-	-	1286	1768	1286	2031	1640	3571	-	-	1587	2333	1587	2680
9	1587	2333	2000	3079	1781	2680	1459	2031	1459	2333	1811	4184	1587	2680	1781	2680	1781	3079
8	1781	2680	2244	3571	-	-	1655	2333	1655	2680	2000	4903	1781	3079	2000	3079	2000	3571
7	2000	3079	2519	4184	2000	3099	1877	2680	1877	3079	2208	5744	2000	3571	2244	3571	2244	4184
6	2244	3571	2828	4903	2244	3571	2130	3079	2130	3571	2438	6730	2244	4184	2519	4184	2519	4903
5	2519	4184	3174	5744	2591	4184	2416	3571	2416	4184	2691	7885	2519	4903	2828	4903	2828	5744
4	2828	4903	3563	-	2828	4903	2740	4184	2740	4903	2971	9238	2828	5744	3174	5744	3174	6730
3	3174	5744	-	-	3174	5744	3108	4903	3108	5744	3281	10823	3174	6730	3563	6730	3563	7885
2	3563	6730	4000	-	3563	6730	5526	5744	3529	6730	-	-	3563	7885	4000	7885	4000	-
1	4000	7885	-	-	4000	7885	4000	6730	4000	7885	4000	-	4000	9238	-	-	-	-

rationale for the longer time period for SPEAK was that subjects already had at least several months prior experience with MPEAK.

During weeks one and two of A_1 , subjects practiced responding to CNC word list one as the speech processor program was modified and adjusted. During the last two weeks of A_1 , data were collected as subjects responded to two of the CNC word lists from lists two through ten.

The length of B_1 was seven weeks. The initial SPEAK program was put on the Spectra 22 processor at the end of the A_1 period. During the following five weeks, processor adjustments were made. Subjects practiced responding to CNC word list one during weeks 5, 8, and 9. Data were obtained during the last two weeks as subjects responded to another two CNC word lists from lists two through ten.

During the next time period (A_2), subjects were given back their Mini Speech Processors with the original MPEAK programs for three weeks. They were evaluated for the last two weeks of A_2 .

At the end of A_2 , subjects switched back to the Spectra 22 processor with the SPEAK program. This was the B_2 time period. B_2 , like A_2 , was for three weeks with patients evaluated during the last two weeks of the period.

Analysis of Word Recognition Data

Data were analyzed for each subject and the group using a separate two-by-two Analysis of Variance (ANOVA). Separate analyses were conducted for the CNC word test scored according to words and phonemes. The factors analyzed were the two speech coding strategies (MPEAK and SPEAK) and the two time periods (A_1, B_1 and A_2, B_2). Main effects and interactions were determined by a full factorial model.

The mean scores for each speech coding strategy are an average across four lists presented during the four evaluation sessions for each individual as well as the group.

Subjects' responses to the CNC words also were analyzed according to the three phonemes in each word: initial consonants, medial vowels, and final consonants. For each of the three phoneme groups, confusion matrices were constructed for the group and for individual subjects. For the group (e.g., Figures 4, 6, and 8) and for each subject (see Appendix A), each phoneme is represented in a confusion matrix with a raw score and a percent correct score for each coding strategy. In addition, all data are represented in two graphic forms (e.g., Figures 5, 7, and 9 and Appendix A). In the first form, the actual scores

for each phoneme are plotted as a function of strategy. In the second form, the percentage better (or worse) the group and each subject performed using the two strategies is plotted. That is, the score for each phoneme with MPEAK is subtracted from the score for SPEAK. The most frequent errors for initial consonants, medial vowels, and final consonants were examined for the group and for each subject. Originally, an information transmission analysis was planned to examine the percent of each feature of speech that was transmitted with each strategy. However, because the CNC word lists are made up of actual words instead of nonsense syllables, the effects of co-articulation on surrounding phonemes must be taken into consideration when performing the analysis. This analysis is beyond the scope of this paper; it will be included in a future paper.

Results

Group Word and Phoneme Scores

The ANOVA results for the group data showed a highly significant difference for word and phoneme scores between speech coding strategies. For words, the group scored significantly higher with SPEAK (41.9%) than with MPEAK (33.1%) [$F(1,8)=23.61$, $p<0.001$]. For phonemes, the group scored 65.0% with SPEAK and 58.9% with MPEAK. This was also a highly significant improvement in scores for the SPEAK strategy [$F(1,8)=19.12$, $p<0.001$]. There was no interaction effect between speech coding strategies and subjects [words: $F(1,8)=1.48$, $p=0.185$; phonemes: $F(1,8)=1.66$, $p=0.129$].

The mean scores for each of the nine subjects for words and phonemes using each strategy are shown in Figures 2 and 3. For MPEAK, mean scores for individual subjects ranged from 9.5 to 47.5% for words and from 30.5 to 73.5% for phonemes. For SPEAK, mean scores for individual subjects ranged from 15.5 to 58.5% for words and 36.3 to 79.3% for phonemes.

Results of the ANOVA indicate that three subjects' (1, 7, and 9) CNC word scores were significantly higher with SPEAK than MPEAK (Figure 2); for these words scored

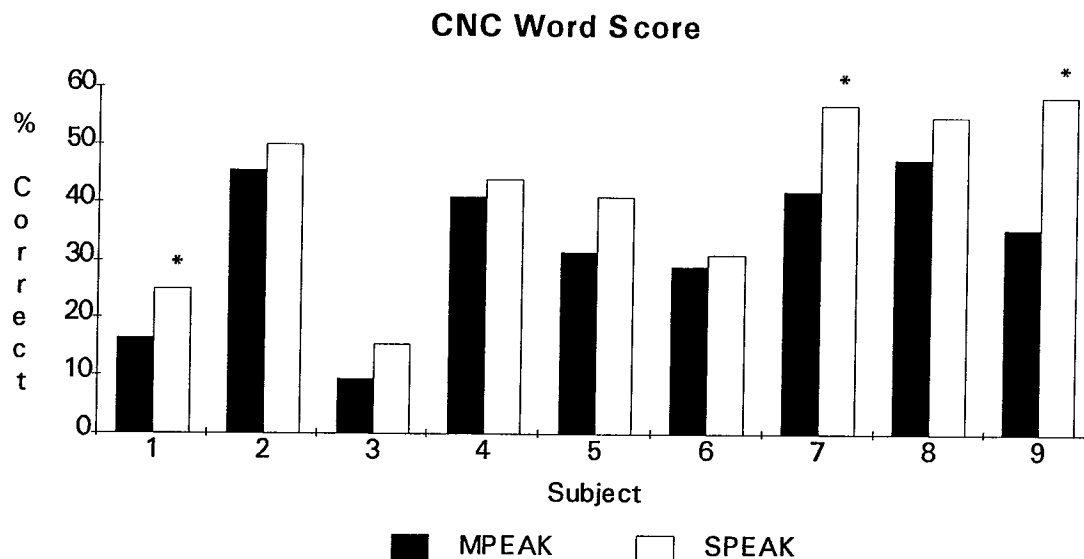


Figure 2. Mean Scores for each subject for CNC words. * Significantly different scores.

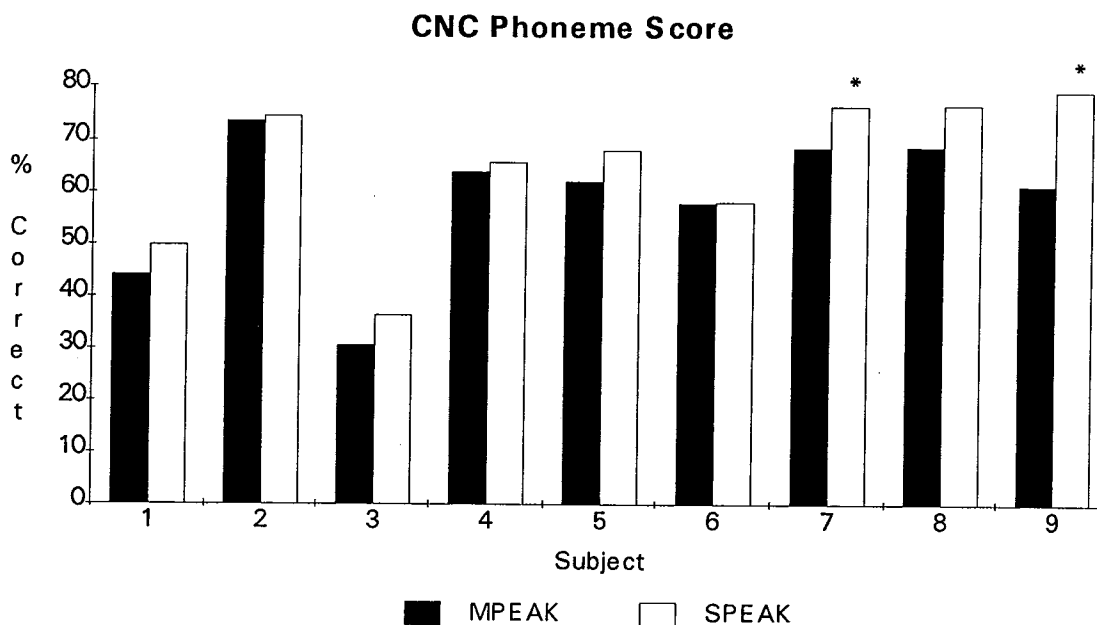


Figure 3. Subjects' mean scores for individual phonemes in CNC words. * Significantly different scores.

according to percent of phonemes correct, two subjects' scores were significantly higher with SPEAK than MPEAK (Figure 3). Subject 1's word scores were 8.5% higher [$F(1,4)=11.6$, $p=0.027$] using the SPEAK strategy. Subject 7 scored 15% better with SPEAK for word identification [$F(1,4)=14.5$, $p=0.016$] and 8% better with SPEAK for phoneme identification

[$F(1,4)=26.8, p=0.007$]. Subject 9's word score was 23% better [$F(1,4)=9.9, p=0.03$] and phoneme score was 18.1% better [$F(1,4)=12.8, p=0.023$] with SPEAK. Only subject 7 had a significant learning effect for words and phonemes from the first to the second half of the experiment ($p \leq 0.05$).

Analysis of Group Initial Consonant Data

Confusion matrices of initial consonants for the MPEAK and SPEAK speech coding strategies are shown in Figure 4 for the group data. Although fewer errors occurred when subjects used the SPEAK strategy, the same initial consonants were a problem with both SPEAK and MPEAK. The initial consonants /p/, /m/, and /l/ had the most errors. In MPEAK, /p/ was most often responded to with /t/, but with SPEAK it was most often responded to with /k/. /p/ and /t/ differ in the center-frequency energy of the burst. /t/ has a band of high-frequency energy, and /p/ has a center of relatively low-frequency energy and /k/ has a mid-frequency center of energy in the burst. With SPEAK, /t/ was rarely confused with /p/ indicating that the difference between the low- and high-frequency burst energy was better transmitted with SPEAK than MPEAK. The closer spacing of the frequency band assignment to electrodes for SPEAK (versus MPEAK; see Table 2) in the frequency regions of the bursts of /p/ and /k/, and the lack of stimulation on band electrodes with SPEAK (that are in the frequency region of /t/ with MPEAK) both contributed to /k/ being the most frequent error response for /p/ with SPEAK. For both strategies, the most common error for /m/ was /l/; however, there were 8% fewer /l/ errors for /m/ with SPEAK than MPEAK, and the mean score for /m/ increased from 27 to 42% correct. For /m/, there is a strong concentration of low-frequency energy with the second formant for male talkers at approximately 750 Hz. The first formants of /m/ and /l/ are essentially the same. There is a large separation between the second and third formants of /l/, with an antiresonance between them. With MPEAK, only one electrode is stimulated for peak energy below 1000 Hz during each cycle; this stimulation would represent either the first or second formant of /m/ and the first formant of /l/.

A. MPEAK-raw score

	RESPONSE																				-		
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L
P	50	3	20	1	13	2	2									12	2	2	2		1	2	6
B	2	71		7	1	9	6	3			1				4	1	2	3			2	2	6
T	4		71	5	18								1	1									1
D		17	1	71	1	8	2												1			1	1
K	12	1	25	1	73				1				3		4							1	5
G	4	6		23		32	2	1						1		1	2	1			1		1
F	1	7	3	2	1	2	36	1			11		1	1		7		1				1	3
V		7	2		1	3		9											2				2
TU	3	3		1	1		6		2		2					2							1
TV	1	3		3		1	1				1				1	1	2	2				1	1
S		1									104		8	3				1			1		
Z				3			1											1					
SH											15		36	7		1							2
CH		2	7		3						2		4	39									2
J			3	2	1	1	1								42	1					1		1
H	9	6	3	3	4	2	7	1						3	64	2							3
M	1	8		1		3		1							3	28	10	8				24	17
N		2		3		2										6	35	2			3	11	14
W		12	1		1	3	1									2		41	1			2	22
WH	2	6	1		1		5											7	2			1	3
Y				2		7									1		1				15		
L	1	15	1	4	4	5								3	3	6	6	11	1		3	55	19
R	3	3	1	1	2		1							1	1	10	5	11			1	16	78
	93	173	139	133	125	80	71	16	3	2	136	0	50	56	53	104	64	68	89	4	26	116	162
																						37	53.1%

MPEAK-% correct

	RESPONSE																				-		
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L
P	42	3	17	1	11	2	2								10	2	2	2		1	2	5	7
B	2	59		6	1	8	5	3			1				3	1	2	3			2	2	5
T	4		69	5	17								1	1									1
D		16	1	66	1	7	2												1			1	1
K	10	1	21	1	61				1				3		3								5
G	5	8		31		43	3	1								1	3	1			1		1
F	1	9	4	3	1	3	46	1			14		1	1		9		1				1	4
V		23	6		3	10		29							3		10		6				4
TU	14	14		5	5		29		10		10				3	10			6			6	5
TV	6	17		17		6	6			6					6	6	11	11				6	6
S		1									88		7	3								1	
Z				50			17					0						17			17		
SH											25		59	11									3
CH		4	12		5						4		7	68		2							3
J			5	4	2	2	2							4	76	2					2		2
H	8	6	3	3	4	2	6	1						3	59	2							3
M	1	8		1		3		1							3	27	10	8				23	16
N		3		4		3										8	44	3			4	14	18
W		14	1		1	3	1									2		47	1			2	25
WH	7	21	3		3		17											24	7			3	10
Y				7		25									4		4	4			54		4
L	1	11	1	3	3	4								2	2	4	4	8	1		2	40	14
R	2	2	1	1	1		1							1	1	7	4	8			1	12	57
	5	10	8	7	7	4	4	1	0	0	8		3	3	3	6	4	4	5		1	6	9
																						2	53.1%

Figure 4. Initial consonant confusion matrices for the group from CNC word tests using the two speech coding strategies. A. MPEAK strategy.

B. SPEAK-raw score

		RESPONSE																								
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-	
S T I M U S	P	61	3	5	1	16	4	1	1						1	2	11	1							6	113
	B	3	96		4		1	6				1					1	1	1					3	4	121
	T	4	1	85	2	8	1	1				1													2	105
	D		9		82		6	2	1		1	1						2					1		3	108
	K	4		11	1	101									1	1			1						3	120
	G		4		13	1	52					1						1		1			2		3	78
	F	4	10	2	2	1		47				1			1			7	2	1					2	80
	V		9		1			8	6	1	1							1	1	2	2				1	33
	TU	2	4		1			5		4			2					1								19
	TV	2	6		1			2				3							1	1						16
	S		1	1			1						91		16	9								1	1	121
	Z																1	1								2
	SH			2				1					7		53	1		1					1		1	67
	CH			2											3	49	1								1	56
	J				2		2									2	55						1		2	64
	H	8	9	2	3	10	5	5		1	3				1			55	1	1			2		2	108
	M	1	7			3		1				1	1					4	43	6	9	2	1	15	6	102
	N		4		1		2		1	1	1							1	8	51			1	12	2	87
	W		1																		58	1		5	23	89
WH	1	3			2		2										2	1		11	4		1	1	28	
Y				1		1						1							1			15			19	
L	2	4		1	2	3	1		1									11	5	11	3	3	68	18	135	
R		2	1		1	2						1						2	1	9	3		17	90	129	
		92	173	111	116	145	80	82	9	8	12	106	0	75	63	59	88	73	71	100	13	26	123	141	34	64.9%

SPEAK-% correct

		RESPONSE																								
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-	
S T I M U S	P	54	3	4	1	14	4	1	1						1	2	10	1						5	6	
	B	2	79		3		1	5				1					1	1	1					2	3	7
	T	4	1	81	2	8	1	1				1													2	6
	D		8		76		6	2	1		1	1						2					1		3	6
	K	3		9	1	84									1	1			1						3	7
	G		5		17	1	67					1						1		1			3		4	4
	F	5	13	3	3	1		59				1			1			9	3	1					3	4
	V		27		3			24	18	3	3							3	3	6	6				3	2
	TU	11	21		5			26		21		11						5								1
	TV	13	38		6			13			19								6	6						1
	S		1	1			1						75		13	7								1	1	7
	Z													0			50	50								0
	SH			3				1					10		79	1		1						1	1	4
	CH			4											5	88	2								2	3
	J				3		3									3	86							2	3	4
	H	7	8	2	3	9	5	5		1	3				1			51	1	1			2		2	6
	M	1	7			3		1				1	1					4	42	6	9	2	1	15	6	6
	N		5		1		2		1	1	1							1	9	59			1	14	2	5
	W		1																		65	1		6	26	5
WH	4	11			7		7										7	4		39	14		4	4	2	
Y				5		5						5							5			79			1	
L	1	3		1	1	2	1		1									8	4	8	2	2	50	13	8	
R		2	1		1	2						1						2	1	7	2		13	70	7	
		5	10	6	6	8	4	5	1	0	1	6		4	4	3	5	4	4	6		1	7	8	2	64.9%

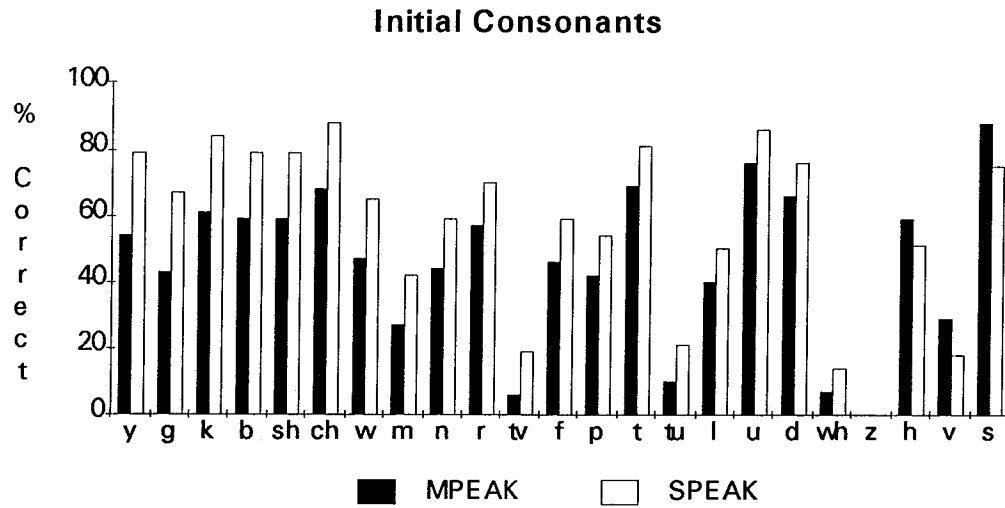
Figure 4. Initial consonant confusion matrices for the group from CNC word tests using the two speech coding strategies. B. SPEAK strategy.

Electrodiagrams of vowels and consonants using the MPEAK strategy show reasonable representation of first formant energy between 280 and 1000 Hz but sparse representation of second formant energy between 800 and 4000 Hz. Without good representation of second formant energy for either /m/ or /l/, and third formant energy carried only by the band electrodes, it is understandable /l/ was the most common error for /m/ with MPEAK. With SPEAK, there is much richer representation of low frequency energy for /m/'s first and second formants, and consequently the score increased 15%. This score increase was associated with the 8% decrease in /l/ errors for /m/.

For both strategies, the most common error for /l/ was /r/; however, the mean score for /l/ increased from 40% to 50% correct with SPEAK compared to MPEAK. This increase in score was related mainly to the decrease in /b/ errors; the /r/ errors remained essentially constant across both strategies (13% and 14%, respectively). The decrease in /b/ errors was due to the strong representation of the stop burst and formant transition with SPEAK. The /l/ errors were not resolved by SPEAK because /l/ and /r/ have essentially the same second formants; their major difference is that /r/'s second and third formants are close together and /l/'s are far apart. It appears that subjects had some difficulty discriminating the difference between the third formant frequencies for these two consonants.

In contrast to nonsense syllables (that are presented an equal number of times for each test), CNC words contain vowels and consonants in proportion to their occurrence in spoken American English. This inequality among the 23 consonants must be considered when looking at the initial consonant confusion matrices presented in Figure 4. The relatively infrequent consonants include: /v, tu, tv, z, wh, and y/. When the initial consonants were examined, subjects had excellent recognition of /s/ (88%) and /j/ (76%) with MPEAK, and /b, t, d, k, s, sh, ch, and y/ (75-88%) with SPEAK (see Figures 4 & 5). Figure 5B shows the group difference score (percent) for each phoneme; for positive values, performance was better with SPEAK, and for negative values, performance was better with MPEAK. There was a 20% or greater improvement using SPEAK for the recognition of the initial consonants

A)



B)

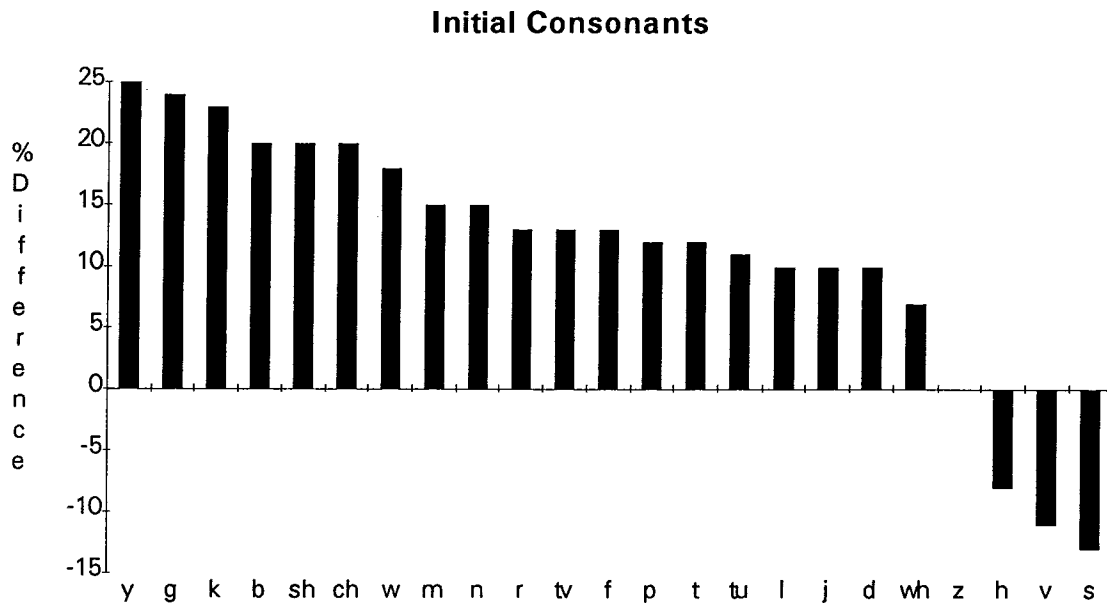


Figure 5. (Percent correct) group mean scores for each consonant from the initial consonant confusion matrices represented in two graphic forms. A) Percent correct scores for the MPEAK and SPEAK strategy. B) Percent difference scores (SPEAK minus MPEAK) for each consonant.

/y, g, k, b, sh, and ch/. With the SPEAK strategy, there was decreased confusion of the stop consonants /g,k, and b/ because of the good representation of the burst frequency information for those consonants. The burst information also decreased confusion of some other consonants. For example, /w/ and /l/ errors for /b/ were less frequent with the SPEAK strategy. Also, good representation of the stop burst at the beginning of /ch/ reduced confusions between /sh/ and /ch/ when SPEAK was used. Figure 5B shows an improvement in recognition for 19 of the 23 initial consonants when the SPEAK strategy was compared with the MPEAK strategy. Only three consonants were better recognized with MPEAK (/h,v, and s/). Better recognition of /s/ with MPEAK was probably due to the stronger stimulation of the high-frequency band electrodes using the MPEAK strategy; there are no band electrodes for the SPEAK strategy.

Table 3 lists initial consonant error patterns for the group for each strategy. Infrequently occurring initial consonants were not included. The two most frequent errors are listed for each frequently occurring initial consonant. The stop consonants /p, b, t, d, k, and g/ were better identified with SPEAK by 16.8% (mean difference score; see Figure 5B). For /p/, 3 out of the 4 of the errors listed for the two strategies were place errors; one was a manner error and none were voicing errors. There were a similar number of /k/ errors for /p/ in each strategy. Although the burst energy for /p/ has a lower center frequency than /k/, the two strategies did not convey this difference well for different reasons. With MPEAK, typically only one electrode responded once to the burst energy and the F2 formant transition was not well transmitted. With SPEAK, more electrodes responded to the burst energy and the F2 formant transition was well represented, but frequency information below 1000 Hz was compressed onto fewer electrodes than with MPEAK. Consequently, the perceived pitch difference between the /p/ and /k/ burst and F2 transition with SPEAK were not optimal. /t/, which was the most frequent error for /p/ in MPEAK, has a much higher burst center frequency than /p/. However, this difference in MPEAK typically is carried on only one

Table 3. Initial consonant error patterns for the group.

STIMULUS	Total Number		Number Correct		Most Frequent Error		Next Most Frequent Error	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
p	118	113	50	61	t(20)	k(16)	k(13)	h(11)
b	120	121	71	96	g(9)	f(6)	d(7)	d(4)
t	103	105	71	85	k(18)	k(8)	d(5)	p(4)
d	108	108	71	82	b(17)	b(9)	g(8)	g(6)
k	120	120	73	101	t(25)	t(11)	p(12)	k(4)
g	75	78	32	52	d(23)	d(13)	b(6)	b(4)
f	78	80	36	47	s(11)	b(10)	b(7)	h(7)
s	118	121	104	91	sh(8)	sh(16)	ch(3)	ch(9)
sh	61	67	36	53	s(15)	s(7)	ch(7)	t(2)
ch	57	56	39	49	t(7)	sh(3)	sh(4)	t(2)
j	55	64	42	55	t(3)	d(2)	d(2)	g(2)
h	108	105	64	55	p(9)	k(10)	f(7)	b(9)
m	105	102	28	43	l(24)	l(15)	r(17)	w(9)
n	80	87	35	51	r(14)	l(12)	l(11)	m(8)
w	87	89	44	58	r(22)	r(23)	b(12)	l(5)
l	138	135	55	68	r(19)	r(18)	b(15)	m(11)
r	136	129	78	90	l(16)	l(17)	w(11)	w(9)

Note: M= MPEAK; S= SPEAK

electrode that often is not sufficient for accurate identification. The /t/ error was resolved with SPEAK because more electrodes responded in rapid succession to the relatively low frequency burst energy of /p/. For /b/, it is interesting to note the most frequent error with SPEAK was /f/. /f/ is a voiceless fricative that was not a problem with MPEAK. The frication energy of /f/ occurs across a broad band of frequencies, and it is of low intensity. The high-frequency band electrodes in MPEAK (that would have been stimulated in response to the /f/) are absent in SPEAK; this lack of stimulation of a high frequency electrode with SPEAK is a possible reason why /f/ is confused with /b/, a voiced stop plosive with very rapid

voice onset time. Basically, the burst /b/ was heard as low intensity, broad band frication instead of a stop burst, and the /f/ was cued by the formant transitions of the succeeding vowel. Because the high-frequency energy in /f/ was transmitted less well with SPEAK than MPEAK, it was confused with /b/. /k/ was the most frequent error for /t/ in both strategies. However, it was reduced by over half with SPEAK (17 to 8%). This improvement occurred because more electrodes responded to the burst, and more first and second formant transition information was conveyed with the SPEAK than MPEAK strategy. It was still an error with SPEAK because the difference in high-frequency energy was not well conveyed for reasons discussed earlier. The same explanation applies when subjects confused /b/ for /d/, the voiced counterparts of /p/ and /t/. Although the errors were reduced by half with SPEAK (16 to 8%), subjects still had some difficulty recognizing the high-frequency burst for /d/ and the immediately preceding and succeeding vowel formants. A /g/ error for /d/, both of which have a very rapid voice onset time, remained constant across strategies; however, percent of errors decreased from 31 to 17%. In contrast, there was a dramatic improvement in recognition of the unvoiced, velar stops, /k/ and /g/ with SPEAK (over 20%). This improvement was clinically important because subjects are unable to lipread these phonemes.

One-third of errors for fricatives with both strategies were stops. The fricatives contain mostly high-frequency energy which is presented on the band electrodes with MPEAK. With MPEAK, /f/ is most often confused with /s/, both of which contain high-frequency energy that is well represented in MPEAK. Therefore, this is a reasonable error. When the high-frequency band electrode information is removed with SPEAK, the most frequent error for /f/ was the phoneme /b/, a voiceless stop, for the reasons described above. For /s/, subjects' scores decreased with SPEAK 13%; errors of /sh/ for /s/ doubled (7 to 13%). All subjects were able to correctly identify the phoneme as voiceless, but when the high-frequency energy represented by band electrode stimulation was removed, the information in /sh/ that was well represented with MPEAK was compressed and became confused with /s/ in

SPEAK. For the affricates /ch,j/, which are composites of a stop and a fricative, there were few errors.

Although the errors for nasals are all reduced for SPEAK, there still were a high number of errors. The most frequent nasal error responses were glides and laterals. The most frequent error for /n/ with MPEAK was /r/. A cue in the identification of /r/ was the formant transitions that occur with the succeeding vowel. Because of the greater first and second formant information conveyed with SPEAK, this error was resolved. Although the /r/ error was resolved for /n/ with SPEAK, it remained the most frequent error for both the glide /w/ and the lateral /l/ in both strategies. The lateral /l/ was also the most common error for /r/ in both strategies. /l, r, m, and n/ have approximately the same first formant. /l/ and /r/ have approximately the same second formant and differ in a high frequency third formant present in /l/. The third formant in /r/ comes right after the second formant; which means the F3 in /r/ may have been perceived as F2. The F3 information of /l/ is apparently not being conveyed.

Analysis of Group Medial Vowel Data

Confusion matrices of the medial vowels for the MPEAK and SPEAK speech coding strategies are shown in Figure 6 for the group data. Once again, subjects performed better overall with SPEAK than MPEAK for vowel recognition (68.1 versus 62.2%) (see Figure 7). The vowel /i/ was particularly troublesome for subjects using both strategies. For MPEAK, /i/ was most often confused with the vowel /e/. These vowels' F1 and F2 formant frequencies are very similar in spectrographic analysis. For SPEAK, /i/ was most often confused with /ee/. /i/ and /ee/ have similar formant frequencies (/ee/'s F2 is slightly higher and F1 is slightly lower in frequency than those of /i/); however, the duration of /ee/ is longer than /i/. Also, the formant frequencies and transitions are affected by the surrounding consonants. The degree of co-articulation that occurs in everyday utterances affects the perception of vowels for the implant user. Another common confusion with SPEAK was the /ao/ vowel sound for the /u/ vowel sound. Both are acoustically similar, but /ao/ contains more high-frequency energy and is

A. MPEAK-raw score

		RESPONSE																		
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO		
Eve	EE	137	6		2								6		1				1	153
It	I	10	115	21	1				10	8	5	2	11	2		1		1	3	190
Met	E	5	4	80	11	1	2	3		1	11	1	9	2		2	2	2	3	139
Have	A	2	1	18	129		1	1	1		3		11	1	4	3	1	6		182
S Heart	AR			2	5	8	1	4			2		1	1	2	6	1	7		40
T Dog	O				1	1	4				1							7		15
I Corn	OR	1	1	1	14	1			14		5				4	2		2		45
M Foot	OO		1	1				1	26	4	2	2	1	3			1	2		44
U Boot	UU	5	1		2				5	63	2			8				5	2	93
L Up	U		3	8	2	2		4	3	1	90	4	4	14	3	2	3	9	2	154
U Bird	ER		4	7	1		1	1	9	4	4	46	4	5	2	1	1	9	2	101
S Say	EI	9	5	11	7	1				2	1		123		9			2	3	173
Go	OH		4	3	3	1	1	4	1	4	4	3	2	80	1	1	4	12		128
I	AI	1	4	8	12			1	1		4	2	6	1	85	5	2	1	1	134
Out	OW			8	1			1			3		1	6		28		4	1	53
Boy	OI			1							1		1	1			22			26
More	AO		1	2	6	2	6	4	2	3	11	2			4	4	3	74	3	130
		170	150	171	197	17	16	38	58	90	149	62	180	127	116	55	40	143	21	62.2%

MPEAK-% correct

		RESPONSE																		
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO		
Eve	EE	90	4		1								4		1				1	9
It	I	5	61	11	1				5	4	3	1	6	1		1		1	2	11
Met	E	4	3	58	8	1	1	2		1	8	1	6	1		1	1	1	2	8
Have	A	1	1	10	71		1	1	1		2		6	1	2	2	1	3		10
S Heart	AR			5	13	20	3	10			5		3	3	5	15	3	18		2
T Dog	O				7	7	27				7				7			47		1
I Corn	OR	2	2	2	31	2		31			11				9	4		4		3
M Foot	OO		2	2				2	59	9	5	5	2	7			2	5		2
U Boot	UU	5	1		2				5	68	2			9				5	2	5
L Up	U		2	5	1	1		3	2	1	58	3	3	9	2	1	2	6	1	9
U Bird	ER		4	7	1		1	1	9	4	4	46	4	5	2	1	1	9	2	6
S Say	EI	5	3	6	4	1				1	1		71		5			1	2	10
Go	OH		3	2	2	1	1	3	1	3	3	2	2	63	1	1	3	9		7
I	AI	1	3	6	9			1	1		3	1	4	1	63	4	1	1	1	7
Out	OW			15	2			2			6		2	11		53		8	2	3
Boy	OI			4							4		4	4			85			1
More	AO		1	2	5	2	5	3	2	2	8	2		2	3	3	2	57	2	7
		9	8	10	11	1	1	2	3	5	8	3	10	7	6	3	2	8	1	62.2%

Figure 6. Medial vowel confusion matrices for the group from CNC word tests using the two speech coding strategies. A. MPEAK strategy.

B. SPEAK-raw score

		RESPONSE																			
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-		
Eve	EE	115	9	3	1							1	22						1	152	
It	I	18	135	15	3				4	3	5	2	11	2		1			3	202	
Met	E	7	9	88	6				1		3	4	9	2					4	133	
Have	A	1	2	21	133	1	1	3			2	4	15	1	5			2	2	193	
S Heart	AR				1	22	1	3	1					2	3			6		39	
T Dog	O						7	2										7		16	
I Corn	OR		1	1	4	2	1	17	1		2				1			11	2	43	
M Foot	OO	1				1			19	1				2				1	2	27	
U Boot	UU	1	2	3					5	68	2		1	17				4	3	106	
L Up	U		4	6	2	2	4	2	10	1	90	3		15	1			17	1	158	
U Bird	ER		1	1		2	5		5	1	9	58		7	1			1	9	100	
S Say	EI	4	2	5	3	1							145					1	1	3	164
Go	OH						1	2	3	7	1	1		104		1	1	13	1	135	
I	AI			1	2	2		2			3	4	9		95	3	4	4	1	130	
Out	OW			3	1	1	1	1			1			10		25		7	2	52	
Boy	OI									1							19	1		21	
More	AO	1	1	1	1	1	3	6	2	2	4			12		1		93	1	129	
		148	166	148	157	35	24	38	51	84	122	77	212	174	106	31	25	176	26	68.1%	

SPEAK-% correct

		RESPONSE																		
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-	
Eve	EE	76	6	2	1							1	14						1	8
It	I	9	67	7	1				2	1	2	1	5	1		0			1	11
Met	E	5	7	66	5				1		2	3	7	2					3	7
Have	A	1	1	11	69	1	1	2			1	2	8	1	3			1	1	11
S Heart	AR				3	56	3	8	3					5	8			15		2
T Dog	O						44	13										44		1
I Corn	OR		2	2	9	5	2	40	2		5				2			26	5	2
M Foot	OO	4				4			70	4				7				4	7	2
U Boot	UU	1	2	3					5	64	2		1	16				4	3	6
L Up	U		3	4	1	1	3	1	6	1	57	2		9	1			11	1	9
U Bird	ER		1	1		2	5		5	1	9	58		7	1			1	9	6
S Say	EI	2	1	3	2	1							88					1	2	9
Go	OH						1	1	2	5	1	1		77		1	1	10	1	8
I	AI			1	2	2		2			2	3	7		73	2	3	3	1	7
Out	OW			6	2	2	2	2			2			19		48		13	4	3
Boy	OI									5							90	5		1
More	AO	1	1	1	1	1	2	5	2	2	3			9		1		72	1	7
		8	9	8	9	2	1	2	3	5	7	4	12	10	6	2	1	10	1	68.1%

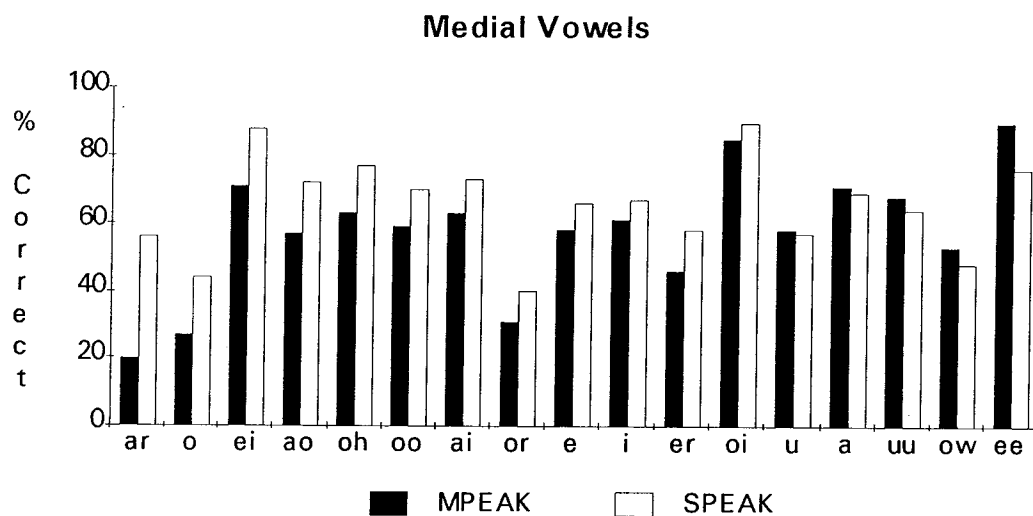
Figure 6. Medial vowel confusion matrices for the group from CNC word tests using the two speech coding strategies. B. SPEAK strategy.

longer in duration than /u/.

The vowels contained in the CNC word lists are representative of the occurrence in everyday spoken American English. Once again, this means that the vowels are unequally represented in the data. The infrequent vowels are /ar,o,or,oo,and oi/. Vowels that were recognized most frequently were /ee/ (MPEAK: 90%; SPEAK: 76%), /oi/ (MPEAK: 85%; SPEAK: 90%), and /ei/ (MPEAK: 71%; SPEAK: 88%). It is important to remember that, although /oi/ was one of the most frequently recognized, it is also one of the infrequently occurring vowels in the CNC word lists. Therefore, less data were collected on this vowel. The vowel /ar/ showed the most improvement from MPEAK to SPEAK (Figure 7B); subjects performed 36% better with SPEAK than MPEAK. The formant transitions are well represented for the vowel /ar/ with SPEAK but not with MPEAK; this difference probably accounts for the dramatic improvement. Again, /ar/ was one of the infrequent vowels. Twelve of the 17 vowels showed improvement in performance with SPEAK (Figure 7B); five vowels were recognized better with MPEAK. The vowel /ee/ showed the greatest decrement with the SPEAK strategy (15%). /ee/ has the highest second formant frequency which is carried by frequency of stimulation on high frequency band electrodes with MPEAK. This high frequency cue was not present with SPEAK.

Table 4 shows the medial vowels error patterns for the group. The two most frequent errors are listed. The first six vowels in table 5 are pure vowels and have distinct formants. The seventh vowel is an r-colored vowel and has the formant structure of the vowel /e/ and the consonant /r/. The last five vowels in table 5 are diphthongs, which are made up of the co-articulation of two vowels and are distinguished from pure vowels by a formant transition within the diphthong. The vowel /ee/, which had the most errors with SPEAK as previously stated, was substituted by the same vowels using each strategy (/i/ and /ei/). However, with the SPEAK strategy, subjects confused /i/ and /ei/ for /ee/ almost four times as much as with the MPEAK strategy; that is, /i/ and /ei/ made up 29% of SPEAK errors and 8% of MPEAK errors. The vowels /ee/ and /i/ are very similar. Both are high, front pure vowels with similar

A)



B)

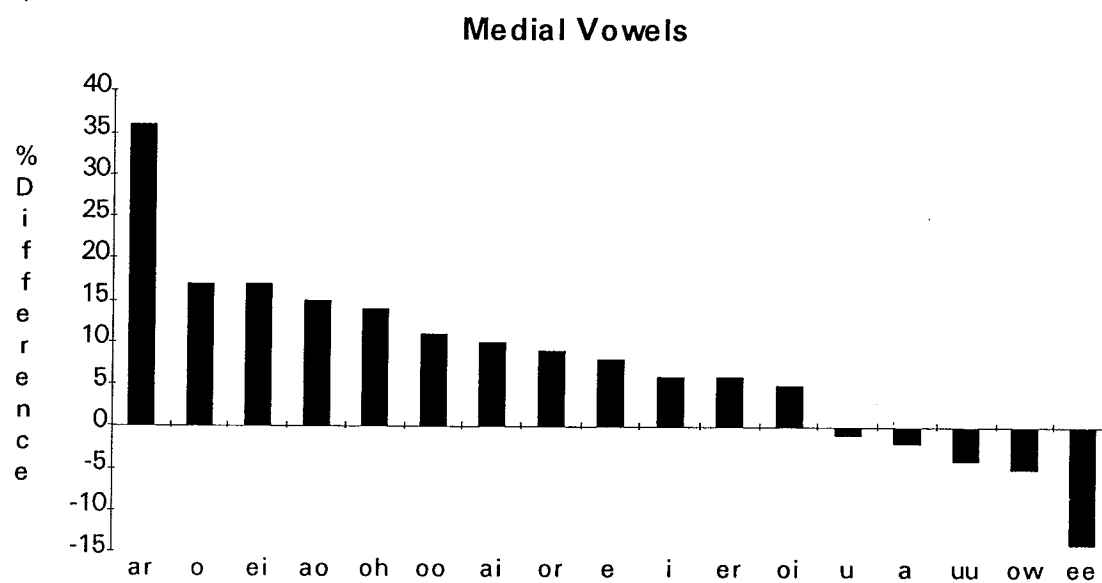


Figure 7. (Percent correct) group mean scores for each vowel from the vowel consonant confusion matrices represented in two graphic forms. A) Percent correct scores for the MPEAK and SPEAK strategy. B) Percent difference scores (SPEAK minus MPEAK) for each consonant.

formant frequencies. Their major difference is /ee/ is a tense vowel and /i/ is lax, therefore, /i/ is shorter in duration. The diphthong /ei/ is very similar to both /ee/ and /i/. It is made of the two vowels /e/ and /i/, both of which have similar characteristics. Therefore, the formant transition between /e/ and /i/ in the diphthong /ei/ was not as easily detectable as for other diphthongs. It is understandable why the group had trouble distinguishing /ee/ from /i/ and

Table 4. Medial vowel error patterns for the group.

STIMULUS	Total Number		Number Correct		Most Frequent Error		Next Most Frequent Error	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
ee	153	152	137	115	i(6)	ei(22)	ei(6)	i(22)
i	190	202	115	135	e(21)	ee(18)	ei(11)	e(15)
e	139	133	80	88	a(11)	i(9)	u(11)	ei(9)
a	182	193	129	133	e(18)	e(21)	ao(6)	ei(15)
uu	93	106	63	68	oh(8)	oh(17)	ao(5)	oo(5)
u	154	158	90	90	oh(14)	ao(17)	ao(9)	oh(15)
er	101	100	46	58	oo(9)	u(9)	ao(9)	ao(9)
ei	173	164	123	145	e(11)	e(5)	ee(9)	ee(4)
oh	128	135	80	104	ao(12)	ao(13)	i(4)	uu(7)
ai	134	130	85	95	a(12)	ei(9)	e(8)	er(4)
ow	53	52	28	25	e(8)	oh(10)	oh(6)	ao(7)
ao	130	129	74	93	u(11)	oh(12)	a(6)	or(6)

/ei/. A very important distinguishing characteristic for identification was the duration cue. Although /ee/ is clearly longer in duration than /i/ based on the tense/lax difference, the effects of co-articulation must be taken into account. When a vowel is in the medial position in a word, its duration is greatly affected by the surrounding consonants (e.g. hid vs. miss); that is, duration is shorter when the vowel is followed by a voiced consonant than an unvoiced consonant. For the vowel /e/, the SPEAK errors of /i/ and /ei/ can be explained by the logic already presented. However, with MPEAK the most frequent errors for /e/ were /a/ and /u/.

The vowels /a/ and /u/ are very different. /a/ is a low front vowel and /u/ is a high back vowel. The fact that these vowels were confused with the mid front vowel /e/, indicates that the F2 information which distinguishes front from back vowels was not conveyed nor perceived well with MPEAK. Also, this error pattern indicates that the high/low information from F1 probably was not being perceived adequately enough to distinguish between the confused vowels. The vowel /uu/ was better perceived with MPEAK. All errors for /uu/ were back vowels. All errors were confusions of high vs. low positions of articulation. These types of errors, as previously stated, are related to F1 frequency. In MPEAK, more electrodes (6-8) are allocated to this frequency range than with SPEAK (4). The same explanation pertains to the substitutions for /u/, which subjects recognized slightly better with MPEAK.

Five diphthongs are listed in table 4. Eight of the 20 errors listed for diphthongs were diphthongs themselves. With MPEAK, diphthongs were errors for diphthongs only 2 out of 10 times, indicative that subjects are not perceiving the crucial formant transitions within diphthongs. That is, subjects perceived many diphthongs as pure vowels with MPEAK. For SPEAK, over half of the errors for diphthongs were diphthongs (6/10). Clearly, the SPEAK strategy provided valuable formant transition information that the MPEAK strategy did not.

Analysis of Group Final Consonant Data

Confusion matrices of the final consonants from the CNC words for the MPEAK and SPEAK speech coding strategies are shown in Figure 8 for the group data. Overall, the scores for each phoneme were substantially lower for the final consonants than they were for the initial consonants (Figures 9A versus 7A). Furthermore, the final consonants showed the least improvement from MPEAK to SPEAK of the three types of phonemes examined (Figures 9B, 7B, and 5B).

There was improved performance for 11 out of 22 final consonants with SPEAK; performance for 8 consonants decreased. The final consonants contained six infrequent consonants: /tv,sh,zh,j,ng, and r/. The consonants that were recognized best were /sh/

A. MPEAK-raw score

	RESPONSE																							
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER	
P	35	1	32	4	14	1	1		1									1		4		3	97	
B		15		8				1									5	10		7		1	48	
T	6		156	4	15	2	2		1		1			3						1		4	195	
D		3	2	82	2	10		6			3				1		14	2	2		2	6	135	
K	6		47	3	81	3			3		1		1		2		3	1	3			4	158	
G	1	1	4	19	5	26		1			1						6	1	1			1	67	
F	2		9		4	1	28		2		6		1					2				2	57	
V			1	4			1	19		1	1	2	1			2	1	3		5	1	6	48	
TU	3		9	4	9		2		11		5							4		1		1	52	
TV		1		2			3			1								1		4			2	14
S			9	1	1	1					79	1	5		1		1	1				3	103	
Z					1	1					2	52		1		2				2			3	61
SH	1		1		1	1					3	2	26			1							36	
ZH											1	4											5	
CH			6	1	2	1					2		3		39	1		1				1	57	
J				2	1	1					4	2			1	21						1	36	
M	1		2	7				4			1	1					1	1				1	97	
N	1	1	1	10		2		5			1	2					29	26	1	10		8	6	
NG			1	5			1	1									16	97	9	15	1	13	17	191
L			2	2	1	2		3						1			7	7	10	2		1	1	36
R																		5	1	120	1	43	10	191
ER	2		1	2		1		1														5	5	
	58	22	283	160	137	50	38	44	18	2	107	70	38	1	47	28	61	187	26	201	3	145	74	55.2%

MPEAK-% correct

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER		
P	36	1	33	4	14	1	1		1									1		4		3	5		
B		31		17				2									10	21		15		2	3		
T	3		80	2	8	1	1		1		1			2					1			2	11		
D		2	1	61	1	7		4				2			1			10	1	1		1	8		
K	4		30	2	51	2			2		1		1					2	1	2		3	9		
G	1	1	6	28	7	39		1				1						9	1	1		1	4		
F	4		16		7	2	49		4		11		2									4	3		
V			2	8			2	40		2	2	4	2			4	2	4				4	3		
TU	6		17	8	17		4		21		10					4	2	6		10	2	13	3		
TV		7		14				21		7								8		2		2	3		
S			9	1	1	1					77	1	5		1		1	1				3	6		
Z					2	2					3	85		2		3				3			3		
SH	3		3		3	3					8	6	72			3							2		
ZH											20	80		0									0		
CH			11	2	4	2					4		5	68	2			2				2	3		
J				6	3	3					11	6			3	58		3	3			3	2		
M	1		2	7				4			1	1					30	27	1	10		8	5		
N	1	1	1	5		1		3			1	1					8	51	5	8	1	7	11		
NG			3	14			3	3									19	19	28	6		3	2		
L			1	1	1	1		2					1					3	1	63	1	23	5	11	
R																						0	100	0	
ER	2		1	2		1		1														1	59	5	6
	3	1	16	9	8	3	2	2	1	0	6	4	2	0	3	2	3	10	1	11	0	8	4	55.2%	

Figure 8. Final consonant confusion matrices for the group from CNC word tests using the two speech coding strategies. A. MPEAK strategy.

B. SPEAK-raw score

	RESPONSE																				-					
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER			
P	51	1	15	4	25		2											2				2	1	103		
B		28		7	2		1	2									4			1		2	1	48		
T	10		151	1	23	2									3								7	197		
D		4	3	89	3	6		6			1	1						7	2	3		2	9	136		
K	3		26	1	116	2			1		1							1				1	3	155		
G	2	1	1	14	7	34										1		3	1	1			4	69		
F	2	2	14		9	2	23		1											1		2	1	57		
S				12			1	19				1						2	5		7	2	6	55		
V				15	4	6	4		6										2				5	43		
TU	1			1				1										1	3	1			1	3	12	
TV		1																						3	12	
M				5	1						80	3	10		3								2	104		
S				1							6	46		2	3								1	67		
U				1							1		29		3	8		1	1				1	36		
L					1		1																1	2	36	
SH																								1	2	36
ZH												1													2	36
U																									2	36
S				2		3		1							48	1									55	
CH					1	1			1							29						1	1	1	36	
J										1															36	
M	2		4	4		4	1	1				3					25	11	1	26		6	6	94		
N	2	1	3	16		1		6				1					11	83	4	18		26	20	192		
NG			3	4	1	1		2			1							7	13	2		1	1	36		
L		1	1	3		4		4									3	3		136		16	14	185		
R																							4	4	4	
ER				7	1	1													4		26	1	69	5	114	
	73	39	244	169	199	57	34	42	8	1	90	56	39	2	57	39	46	133	23	222	1	135	91	59.7%		

SPEAK-% correct

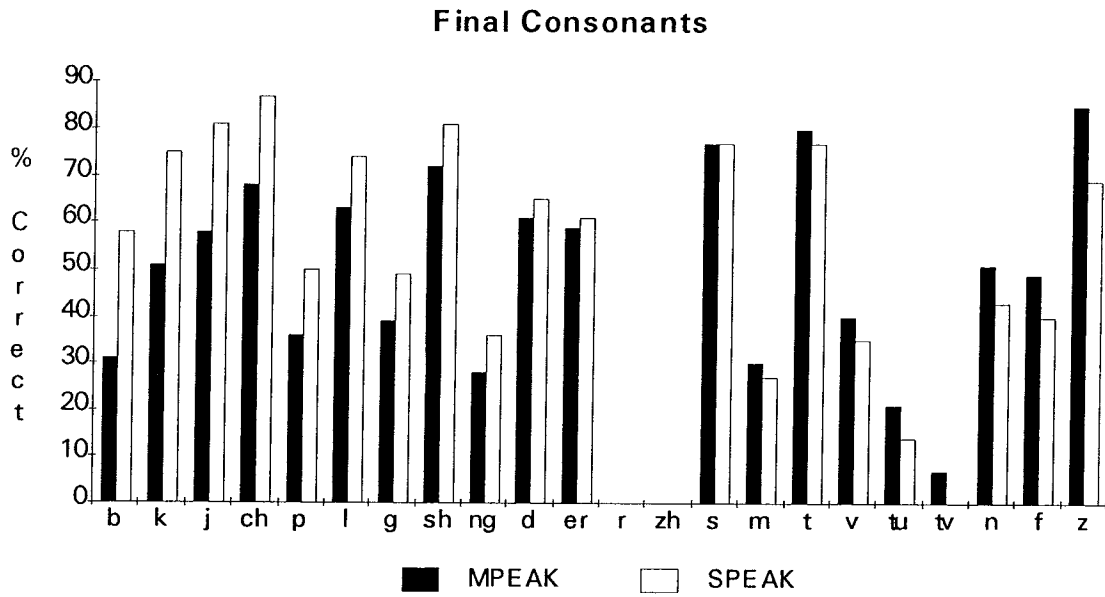
	RESPONSE																				-				
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER		
P	50	1	15	4	24		2											2				2	1	6	
B		58		15	4		2	4									8			2		4	2	3	
T	5		77	1	12	1									2								4	11	
D		3	2	65	2	4		4			1	1						5	1	2		1	7	8	
K	2		17	1	75	1			1		1							1				1	2	9	
G	3	1	1	20	10	49										1		4	1	1			6	4	
F	4	4	25		16	4	40		2											2		4	2	3	
S				22			2	35				2						4	9		13		11	3	
V				9	14		9		14									5				4	12	2	
TU	2		35	8				8			0						8	25	8			8	25	1	
TV		8																						1	
M				5	1						77	3	10		3								2	6	
S				1							9	69		3		12		1	1				1	4	
U											3		81		8									2	
L					3		3							0				50						0	
SH																								0	
ZH																								0	
U																								0	
S				4		5		2							87	2		50						3	
CH																								3	
J					3	3			3							81					3		3	2	
M	2		4	4		4	1	1				3					27	12	1	28		6	6	5	
N	1	1	2	8		1		3				1					6	43	2	9		14	10	11	
NG			8	11	3	3		6			3							19	36	6		3	3	2	
L		1	1	2		2		2									2	2		74		9	8	10	
R																						0	100	0	
ER				6	1	1													4		23	1	61	4	6
	4	2	14	9	11	3	2	2	0	0	5	3	2	0	3	2	3	7	1	12	0	8	5	59.7%	

Figure 8. Final consonant confusion matrices for the group from CNC word tests using the two speech coding strategies. B. SPEAK strategy.

(MPEAK: 72%, SPEAK: 81%), /s/ (MPEAK & SPEAK: 77%), /t/ (MPEAK: 80%, SPEAK: 77%), and /z/ (MPEAK: 85%, SPEAK: 69%). However, the only well-recognized final consonant that was better recognized with SPEAK than MPEAK was /sh/ (which was an infrequently used stimulus). When the percent improvement of SPEAK over MPEAK was examined (Figure 9B), the final consonants /b,k, and j/ were recognized by these subjects over 20% better using SPEAK. These are stops or contain a stop; improvement can be credited to the better representation of burst frequency and formant transition to the burst that was well-represented with SPEAK and not with MPEAK. Also, the improvement of /j/ with SPEAK was associated with the stop burst contained in /d/, at the beginning of the /j/ sound.

Table 5 shows final consonant error patterns for the group. Consonants can be divided into stops (/p, b, t, d, k, g/), fricatives (/f, v, tu, s, z, ch/), nasals (/m,n/), and laterals (/l, er/). With the exception of /t/, all subjects recognized the stops better with SPEAK. There were no voicing errors with the final stop consonants. The most frequent errors for /p/ changed from /t/ with MPEAK to /k/ with SPEAK. This same change in errors from /t/ to /k/ for /p/ occurred for the initial consonant /p/, and for the same reasons discussed above. When /b/ was a stimulus, the common errors with both strategies were the nasals (/n, m/) and /d/. However, when /d/ was a stimulus, the most common errors were the nasal /n/ (both strategies) and "no response" (SPEAK). When subjects gave no response to the stimulus, it wasn't heard. This response was much more common with the final consonants, especially for the nasals (/n, m/) and laterals (/l, er/). The final nasals appeared to contain little formant energy. The same was true of the laterals. The only time a stop was responded to with "no response" was for the /d/. Nineteen of the 24 most frequent errors for stops were stops; that is, they were place errors. Subjects were able to detect the stop manner cue, but often were unable to discriminate low intensity, spectral (or place) cues. However, the fact that all stops improved with SPEAK, except /t/, indicates subjects are perceiving burst frequency information and formant transitions better with this strategy. The final fricatives, with the exception of /ch/ and /s/, were all perceived better with MPEAK; (i.e., /ch/ was identified

A)



B)

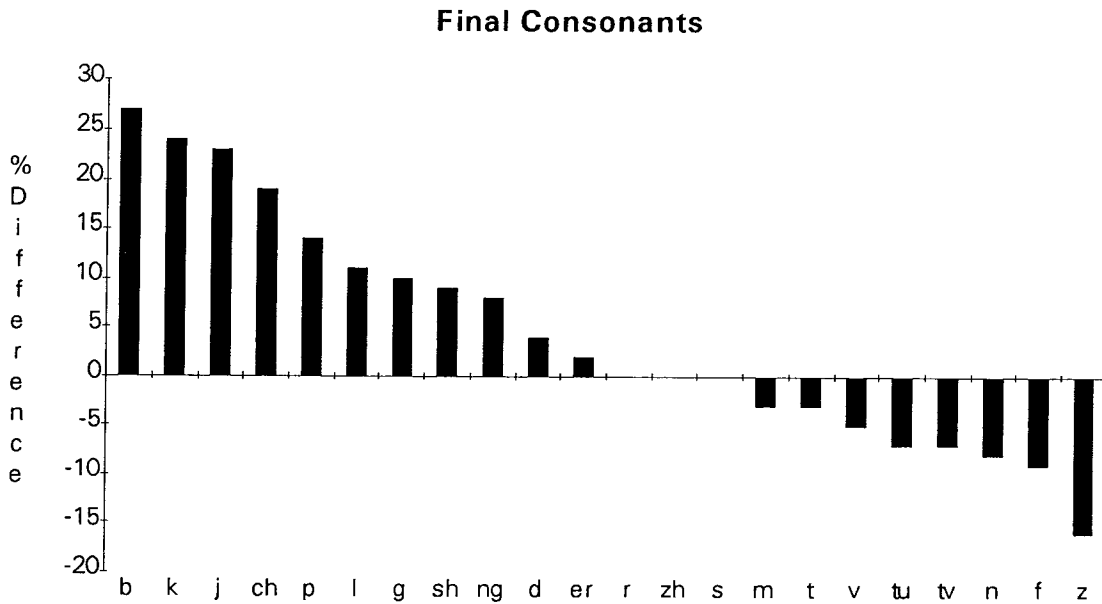


Figure 9. (Percent correct) group mean scores for each consonant from the final consonant confusion matrices represented in two graphic forms. A) Percent correct scores for the MPEAK and SPEAK strategy. B) Percent difference scores (SPEAK minus MPEAK) for each consonant.

Table 5. Final consonant error patterns for the group.

STIMULUS	Total Number		Number Correct		Most Frequent Error		Next Most Frequent Error	
	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>	<u>M</u>	<u>S</u>
p	97	103	35	51	t(32)	k(25)	k(14)	t(15)
b	48	48	15	28	n(10)	d(7)	d(8)	m(4)
t	195	197	156	151	k(15)	k(23)	p(6)	p(10)
d	135	136	82	89	n(14)	NR(9)	g(10)	n(7)
k	158	155	81	116	t(47)	t(26)	p(6)	p(3)
g	67	69	26	34	d(19)	d(14)	n(6)	k(7)
f	57	57	28	23	t(9)	t(14)	k(4)	k(9)
v	48	55	19	19	NR(6)	d(12)	l(4)	l(7)
tu	52	43	11	6	t(9)	t(15)	k(9)	k(6)
s	103	104	79	80	t(9)	sh(10)	sh(5)	t(5)
z	61	67	52	46	s(2)	j(8)	j(2)	s(6)
ch	57	55	39	48	t(6)	k(3)	sh(3)	t(2)
m	97	94	29	25	n(26)	l(26)	l(10)	n(11)
n	191	192	97	83	NR(17)	er(26)	m(16)	NR(20)
l	191	185	120	136	er(43)	er(16)	NR(10)	NR(14)
er	111	114	66	69	l(24)	l(26)	NR(6)	d(7)

better with SPEAK; /s/ was identified equally well with both strategies). The three high-frequency bands available with MPEAK allowed for better recognition of fricatives, which consist of primarily high-frequency energy. It is not surprising that /ch/ was the one fricative better perceived with SPEAK. At the beginning of /ch/ is the stop /t/; the other portion is the fricative /sh/. For this reason, subjects had more information available for identification of /ch/. Most of the errors for fricatives using SPEAK were stops. Without stimulation of the high-frequency band electrodes with MPEAK, the fricatives were often perceived as stops with the SPEAK strategy. The errors for nasals were other nasals, laterals, and "no response". For /m/, the error /n/ is decreased by over half with SPEAK. The F2 information available with

SPEAK enabled subjects to tell the difference between /m/ and /n/. However, the /l/ for /m/ errors more than doubled with SPEAK. This finding suggests that the high frequency energy for the F3 of /l/ was not conveyed well with SPEAK, and because the first and second formants of /l/ and /m/ were very similar, they sounded the same. For the laterals, it was interesting that the /er/ for /l/ errors were greatly decreased from MPEAK to SPEAK; however, the /l/ for /er/ errors were the same for the two strategies. This asymmetry of responses was probably related to differences in the preceding vowels.

Analysis of Individual Differences

Although analysis of group performance across subjects is important for determining error patterns, it is also important to examine each individual's performance. Analysis of individual errors provides information about how the individual perceives speech sounds and whether programming parameters are being utilized maximally for each subject. Individual differences in performance have already been briefly discussed (Figures 2 & 3); the following is a brief discussion of the individual subjects' error patterns.

Table 6 lists initial consonant errors for each subject. Only errors that occurred at least 20% or more are listed. The "bottom effect" occurred when a subject was unable to correctly identify a phoneme in any of the words that contained it. All, except subjects 1,6, and 9, had a "bottom effect" for the phoneme /tv/ with SPEAK. Both subject 1 and 6 actually had /tv/ errors decreased by 50% and 33%, respectively, with SPEAK; whereas subject 9's errors for /tv/ decreased less than 20%. Despite the fact that six of the nine subjects had a "bottom effect" for /tv/ with SPEAK, the improvement in group score for this phoneme with SPEAK compared to MPEAK was 13%. Although these numbers seem dramatic, it is important to remember /tv/ was an infrequent stimulus that subjects were only given a chance to respond to 18 times with MPEAK and 16 times with SPEAK. The group's greatest improvement with SPEAK was for /y/ (25%). However, subjects 1 and 6 actually had increased errors for /y/ with SPEAK of 67% and 75%, respectively. As a group, /s/

Table 6. Subjects and their initial consonant confusions associated with 20% or greater increase or decrease in phoneme score with the SPEAK strategy; subjects with ceiling[†] or bottom[‡] effects with both strategies.

	Errors Decreased with SPEAK	Errors Increased With SPEAK	Ceiling Effect	Bottom Effect
Subject 1	sh(59%) tv(50%) v(50%) f(45%) d(34%) ch(34%) b(33%) k(23%) l(20%)	t(25%) h(25%) j(29%) s(33%) y(67%)	j (M)	tu,z,w,wh,y (S) v,tu,tv,z,m,wh (M)
Subject 2	w(67%) g(51%) f(33%) y(33%) p(24%) n(23%)	d(25%) h(25%) tu(75%)	sh,ch,j,y (S) tu,ch,j (M)	tv,z (S) tv,z,wh (M)
Subject 3	h(67%) y(50%) w(44%) p(42%) k(40%) d(33%) r(32%) g(27%)	ch(24%) sh(43%) s(54%)		v,tu,tv,z,wh (S) p,v,tu,tv,z,h,wh,y (M)
Subject 4	n(38%) y(33%) j(33%) tu(33%) k(21%) b(20%) l(20%)	f(32%) v(42%) h(42%)	k,j,y, (S) d,s (M)	tv (S) tu,tv,z,wh (M)
Subject 5	sh(57%) b(49%) j(36%) n(34%) ch(25%) f(22%) w(20%)	wh(25%) v(33%) h(50%)	s,ch,y (S) s,y (M)	v,tv,z,wh (S) tv,z (M)
Subject 6	sh(66%) ch(57%) tv(50%) l(40%) g(39%) n(20%)	wh(25%) v(33%) h(50%) y(75%)	ch,j (S) s,j (M)	v,tu,z,wh,y (S) tu,tv,z (M)
Subject 7	y(50%) m(49%) h(34%) w(25%) t(25%) d(25%) ch(20%)	s(24%)	t,sh,ch,y,r (S) sh (M)	tu,tv,z (S) tu,tv,z,wh (M)
Subject 8	k(50%) b(46%) m(40%) w(34%) y(33%)	p(27%) l(29%) n(38%)	b,t,k,sh,ch,j,y (S) j (M)	tu,tv,z,wh (S) tu,tv,z,wh (M)
Subject 9	y(100%) r(67%) n(67%) ch(67%) g(62%) t(58%) d(50%) w(50%) tu(50%) s(42%) j(40%) p(39%) k(39%) wh(25%) b(21%)	v(25%)	b,d,g,s,ch,j,y (S)	v,z (S) tu,z,wh,y (M)

[†]Ceiling effect: initial consonant score of 100%.

[‡]Bottom effect: initial consonant score of 0%.

errors increased the most with SPEAK (13%). However, only three subjects showed increases in /s/ errors of 20% or more. Because /s/ was a frequent stimulus, it was of interest to further investigate why some subjects did well with this stimulus and other did not. It has already been hypothesized that subjects identified /s/ better with MPEAK because of the three high frequency bands, but why do some subjects identify /s/ better with SPEAK? This issue will be addressed by further study. The "ceiling effect" occurred whenever a subject correctly identified a phoneme 100% of the time. Across subjects, the "ceiling effect" occurred 32 times with SPEAK and only 11 times with MPEAK.

Further investigation is needed to discover why some subjects can perform the same overall and have very different error patterns. For example, subjects 1 and 5 (see Appendix A) performed approximately the same overall for initial consonants, but had few of the same phoneme errors that increased and decreased with SPEAK.

For medial vowels, the group correctly identified /oi/ with SPEAK 5% better than with MPEAK. This was the smallest MPEAK to SPEAK improvement of all the vowels. This small improvement occurred because 8 of 9 subjects had a "ceiling effect" with /oi/ for the SPEAK strategy (Table 7), and 6 of 9 subjects also had a "ceiling effect" with /oi/ for MPEAK. This is another example of the importance of looking at the group data versus the individual data. The group data would indicate that there was only a small improvement for the vowel /oi/. In reality, it was the best recognized vowel with SPEAK and the next best recognized with MPEAK. The group data shows identification of the vowel /ar/ improved most with SPEAK. Individual data also support this. Eight out of 9 subjects show decreased SPEAK errors with /ar/. However, it is important to remember that both /oi/ and /ar/ are infrequently occurring vowels in the CNC word lists. Five of 9 subjects had a ceiling effect with /oo/ with one or both strategies; 4 of the 5 subjects had it with SPEAK. Six subjects had a bottom effect with /o/; 2 subjects had it with both strategies, 3 had it with MPEAK only, and 1 had it with SPEAK. Despite these individual differences, the group identified /oo/ and /o/ correctly over 10% better using the SPEAK strategy.

Table 7. Subjects and their medial vowel confusions associated with 20% or greater increase or decrease in phoneme score with the SPEAK strategy; subjects with ceiling[†] or bottom[‡] effects with both strategies.

	Errors Decreased with SPEAK	Errors Increased with SPEAK	Ceiling Effect	Bottom Effect
Subject 1	oo(50%) e(48%) i(40%) o(33%) oh(33%) ei(29%) ar(20%)	ai(31%) ow(43%) ao(45%)	oi (S) oi (M)	ar,o (M)
Subject 2	ao(43%) ar(42%) oo(33%)	or(30%)	oo,ai,oi (S) oi (M)	o (S) o (M)
Subject 3	o(50%) er(45%) ao(27%) e(24%) or(20%)	oo(30%) ow(33%) ar(40%) ee(41%) oi(100%)	oi (M)	oi (S) o,or,er (M)
Subject 4	ar(60%) o(50%) i(48%) ei(31%) er(28%) oo(25%)		ee,o,oo,oi (S) oi (M)	ar (M)
Subject 5	oi(67%) ar(50%) or(27%) ei(22%) ai(22%)	u(22%) oo(25%) ow(25%) i(31%) o(50%)	oi (S) o (M)	ar (M)
Subject 6	ar(40%) ow(37%) oo(20%)	ee(29%) or(35%)	oo, oi (S) ee,oi (M)	o (S) o (M)
Subject 7	ar(80%) o(50%) er(50%) ao(27%) ai(23%)	ee(25%) uu(40%)	ar,o,er,ei,ai,oi (S) ee,uu,oi (M)	
Subject 8	o(50%) or(40%) oi(33%)	er(27%) ow(33%)	ee,a,oo,oi (S) oo (M)	o (M)
Subject 9	ar(100%) oo(71%) ao(59%) oh(57%) ai(53%) i(42%) e(35%) oi (33%) er(31%) or(25%)	o(50%)	ar,oo,ei,oh,oi (S)	o (S) ar,or (M)

[†]Ceiling effect: medial vowel score of 100%.

[‡]Bottom effect: medial vowel score of 0%.

Table 8 shows the individual data for final consonants. Recognition of the phoneme /b/ was the most improved for the group with SPEAK. For individuals, the greatest decrease in errors for /b/ with SPEAK occurred only with subjects 4 and 7; however, subjects 5, 8, and 9 had smaller decreases. In contrast to the initial consonants, where the ceiling effect occurred much more often with SPEAK than MPEAK, the "ceiling effect" for the final consonants occurred almost equally for the two strategies (20 phonemes with SPEAK; 21 phonemes with MPEAK). There was also greater variability in individual subjects' performance with the final consonants. In contrast to the initial consonants, two subjects had a greater increase than decrease in number of final consonant errors with SPEAK. Another important variable in evaluating final consonants is number of "no responses" per subject compared to the group. The group had "no response" 91 times with SPEAK and 74 times with MPEAK; a difference of 17. However, only two subjects had a difference in "no responses" from SPEAK to MPEAK of greater than three.

Individual confusion matrices and graphical representation of improvements/decrements are included in Appendix A.

Discussion

Previous studies have shown that cochlear implant patients achieve significantly higher speech recognition scores with the SPEAK speech coding strategy when compared to the MPEAK speech coding strategy (Skinner et al, 1994; Holden et al, in press), particularly for sentences in noise (71-80% of subjects had significantly higher scores at the three signal-to-noise ratios; Skinner et al, 1994). Because the data analyzed in the present study are a subset of the Skinner et al study, it was expected that the group CNC word and phoneme scores for these nine subjects would be significantly higher ($p < 0.001$) when they used the SPEAK strategy than when they used the MPEAK strategy (words: 41.9% versus 33.1%; phonemes: 65.0% versus 58.9%).

The purpose of the present study was to analyze the change in phoneme recognition of initial consonants, medial vowels and final consonants to better understand what factors contributed to the improvement in word recognition using the SPEAK strategy in comparison to using the MPEAK strategy. Similar studies have been made of the same nine subjects' responses to medial vowel and medial consonant nonsense syllable tests used in the field study (Skinner et al, manuscripts in preparation). The medial vowels were presented in a /hVd/ context and the medial consonants were presented in a /aCa/ context. Because the same male talker recorded both nonsense syllable tests and the CNC word lists, the results are more easily compared than if different talkers had recorded the tests. For the group, there was no significant difference in mean score for the two strategies for the medial vowel test (MPEAK: 72.3%; SPEAK: 73.4%). However, for the medial consonant test, the mean score with SPEAK (76.2%) was significantly higher ($p < 0.001$) than the mean score with MPEAK (67.3%). For the medial vowels, improvement in recognition of r-colored vowels was offset by decrement in recognition of pure vowels. For the medial consonants, there was a marked increase in recognition of the velar stop consonants, /g/ and /k/, and a slight decrease in accurate identification of the nasals with SPEAK.

Comparison of Phoneme Identification in CNC Words and Nonsense Syllables

When nonsense syllables are used, subjects do not get as much formant transition information from the surrounding phonemes (which remain the same for every phoneme) and vowel duration is longer with nonsense syllables; the purpose of using a nonsense syllable is to assess the degree to which an individual perceives the medial vowel when the surrounding consonants are controlled for each different vowel. Although this is an effective way of looking at data, the effects of co-articulation must be assessed to obtain a better representation of how subjects perform in everyday life. An information transmission analysis of data obtained using actual words, when surrounding phoneme information is taken into account, will show the effects of co-articulation. Although the study of phoneme recognition

Table 8. Subjects and their final consonant confusions associated with 20% or greater increase or decrease in phoneme score with the SPEAK strategy; subjects with ceiling[†] or bottom[‡] effects with both strategies.

	Error Decreased with SPEAK	Errors Increased with SPEAK	Ceiling	Bottom
Subject 1	sh(50%) l(36%) k(27%) j(25%) ng(25%)	er(27%) n(33%) z(33%)	j(S)	f,tu,tv,zh,r (S) b,tv,zh,ng,r (M)
Subject 2		ng(25%) g(29%) m(55%)	b,s,sh,ch,j (S) b,t,g,f,s,z,sh,ch,j (M)	tv,zh,ng,r (S) tv,zh,r (M)
Subject 3	j(75%) sh(50%) ng(50%) d(33%) ch(31%) g(25%) k(20%)	t(30%) z(33%) s(34%)		v,tu,tv,zh,r (S) v,tu,tv,g,zh,j,ng,r (M)
Subject 4	b(60%) ng(50%) er(27%) j(25%) g(20%)	sh(25%) n(48%) f(50%)	ch (S) s,z,sh (M)	f,tu,tv,r (S) b,tu,tv,zh,r (M)
Subject 5	ch(50%) b(43%) k(30%) n(26%) sh(25%) z(21%) f(21%)	v(30%) m(36%)		tv,zh,r (S) tv,zh,r (M)
Subject 6	ch(66%) j(25%) k(24%)	p(22%) m(32%) er(37%) ng(50%) sh(50%) s(58%)	s,sh (M)	tv,zh,ng,r (S) tv,zh,r (M)
Subject 7	b(63%) j(25%) t(23%)	ng(25%) g(31%) tu(50%)	t,s,z,sh,ch,j (S) sh (M)	tu,tv,zh,r (S) tv,zh,r (M)
Subject 8	p(55%) g(45%) m(43%) k(38%) v(34%) b(30%)	tu(25%) f(29%) z(37%) tv(100%)	sh,ch,j (S) f,tv,z,sh,ch,j (M)	tv,zh,r (S) zh,r (M)
Subject 9	g(73%) m(70%) s(55%) ch(50%) ng(50%) t(39%) l(38%) f(38%) p(37%) d(34%) k(30%) er(27%) j(25%) sh(25%) sh(25%) b(23%)		s,sh,ch,j (S)	tv,zh,r (S) tv,zh,m,ng,r (M)

[†]Ceiling effect: final consonant score of 100%.

[‡]Bottom effect: final consonant score of 0%.

in nonsense syllables yields valuable information, the effects of co-articulation of multiple preceding and succeeding phonemes on recognition necessary for identifying words in everyday life are not included. For this reason, a comparison was made between phoneme recognition in the nonsense syllable tests and in the CNC words. Table 9 shows the difference in medial vowel results when nonsense syllables were used (Skinner et al, manuscript in preparation) compared to the results of this study using CNC words. Recordings from the same talker were used for both tests. Seven out of 12 of the medial vowels improved in recognition by at least 10% when CNC words were used. Of the 7 vowels that improved, 5 improved by 16-29%. The two vowels showing the greatest improvement were the back vowels /o/ and /u/, both of which are difficult to lipread. Greater F2 information and better formant transition information from adjacent consonants is responsible for the greater recognition of the medial vowels with SPEAK in CNC words compared to the medial vowels in nonsense syllables.

The same comparison was made for the initial consonants. Skinner et al (manuscript in preparation) looked at vowels and consonants in nonsense syllables in a /hVd/ and /aCa/ context. Table 10 compares the medial consonant results of the Skinner study and the results with CNC initial consonants. All of the initial consonants had greater improvement in CNC words (with SPEAK), than in the medial consonant position, with the exception of /z, v, and s/. The consonants with the greatest improvement in CNC words were /t, j, f, and m/. The greatest improvement in CNC words with SPEAK was for /g/ (24%). However, this improvement was 11% less than the improvement that occurred when /g/ was a medial consonant. The subjects scored 0% for /z/ using both MPEAK and SPEAK, therefore, there was no improvement with either strategy for this consonant. Errors for /v/ and /s/ increased 11% and 13% respectively with SPEAK. Reasons for improvement with the initial consonants in CNC words include higher intensity of initial consonants, a variety of clues in the vowels that follow, and the presence of linguistic cues.

Table 11 compares final consonants in CNC words with the same medial consonants

Table 9. Comparison of medial vowels in nonsense syllables and CNC words; *Increased identification with SPEAK for CNC words compared to nonsense syllables.

% Improvement with SPEAK in Nonsense Syllable Medial Vowels		% Improvement with SPEAK in CNC Word Medial Vowels		
hard	↑22%	"heart"	↑38%	*16%
hoard	↑18%	"corn"	↑5%	
hud	↑4%	"up"	↓1%	
hawd	↑2%	"dog"	↑15%	*13%
heed	0%	"eve"	↓14%	
hod	↓14%	"dog"	↑15%	*29%
hood	↓11%	"foot"	↑17%	*28%
head	↓10%	"met"	↑9%	*19%
herd	↓7%	"bird"	↑12%	*19%
had	↓7%	"have"	↓2%	
hid	↓4%	"it"	↑6%	*10%
whod	↓2%	"boot"	↓3%	

Table 10. Comparison of medial vowels in nonsense syllables and initial consonants in CNC words; * Increased identification with SPEAK for CNC words compared to nonsense syllables.

% Improvement with SPEAK in Nonsense Syllable Medial Consonants		% Improvement with SPEAK in CNC Word Initial Consonants		
aga	↑35%	g	↑24%	
aka	↑22.8%	k	↑23%	
aba	↑17.4%	b	↑20%	*2.6%
asha	↑15.5%	sh	↑20%	*4.5%
ama	↑3.2%	m	↑15%	*11.82%
ana	↑10.9%	n	↑15%	*4.1%
afa	↑1.1%	f	↑13%	*11.9%
apa	↑9.5%	p	↑12%	*2.5%
ata	↓5.0%	t	↑11%	*16%
aja	↓3.9%	j	↑10%	*13.9%
ada	↓4.5%	d	↑10%	*5.5%
aza	↓2.8%	z	0%	
ava	↑6.7%	v	↓11%	
asa	↑5.5%	s	↓13%	

used in Table 10. Although 9 of the 14 initial consonants were better conveyed (over 2% better than medial consonants) with SPEAK in CNC words, only 5 of the fourteen final consonants were better conveyed in CNC words. Compared to the CNC word scores for final consonants, subjects recognized the medial consonants in the nonsense syllables more frequently. The final consonants /b, k, j, t, and p/, in CNC words, showed the highest improvement of all CNC word final consonants; especially /j/, which improved 26.9% in the CNC words. Although /g, sh, and d/ were recognized better in the medial consonant position, they were still better recognized with SPEAK than MPEAK in both positions. Conversely, /n, f, and z/ were better recognized with MPEAK than SPEAK in both the medial and final consonant positions. Final consonants were probably not well perceived in words because they have lower intensity, shorter duration, and there was no subsequent phoneme with formant structure to give further acoustic clues.

Effect of Assignment of Frequency Boundaries to Electrodes on Phoneme Recognition

The decrement in pure vowel and nasal recognition using the default assignment of frequency boundaries to electrodes in the MPEAK/SPEAK field study (see Table 2) indicated that the use of only four electrodes for the frequency region from 150 to 950 Hz was probably not optimal. For this reason, Skinner, Holden and Holden (in press) assessed the effects of changing the frequency boundaries assigned to electrodes in SPEAK. Seven of the 9 subjects from the current study participated. In the default assignment, (same as for the MPEAK/SPEAK field trial) four electrodes were assigned to the frequencies 150-950 Hz. Subjects showed a 3.8% improvement in CNC word scores and a 4.7% improvement in CNC phoneme scores after using the default assignment with the SPEAK strategy for six months. In the experiment, using an A_1, B_1, A_2, B_2 design for 4 months, 6 electrodes were assigned to the frequency range 120-1080 Hz for the experimental condition (B_1 and B_2 time periods). Subjects showed a significant improvement (at the 0.05 level) for both CNC words (absolute

score: 52.0%; ↑4.4%) and CNC phonemes (absolute score: 75.3%; ↑3.2%) using the experimental instead of the default assignment of frequency boundaries to electrodes. In this same experiment, on a vowel test that included pure vowels, r-colored vowels, and

Table 11. Comparison of medial consonants in nonsense syllables and final consonants in CNC words; * Increased identification with SPEAK for CNC words compared to nonsense syllables.

% Improvement with SPEAK in Nonsense Syllable Medial Consonants		% Improvement with SPEAK in CNC Word Final Consonants	
aga	↑35%	g	↑10%
aka	↑22.8%	k	↑24% *1.2%
aba	↑17.4%	b	↑27% *9.6%
asha	↑15.5%	sh	↑9%
ama	↑3.2%	m	↓3%
ana	↑10.9%	n	↓7%
afa	↑1.1%	f	↓9%
apa	↑9.5%	p	↑14% *5.5%
ata	↓5.0%	t	↑3% *2%
aja	↓3.9%	j	↑23% *26.9%
ada	↓4.5%	d	↑4%
aza	↓2.8%	z	↓16%
ava	↑6.7%	v	↓5%
asa	↑5.5%	s	0%

diphthongs, there was a dramatic improvement in diphthong recognition with the experimental condition. The present study also shows greater recognition of pure vowels and diphthongs in CNC words using SPEAK vs. MPEAK (Figure 7B).

Comparison of Phoneme Recognition with SMSP and SPEAK Speech Coding Strategies

A precursor to the Spectra 22 speech processor and SPEAK speech coding strategy was the Spectral Maxima Sound Processor (SMSP). McKay and McDermott (1993) compared several subjects' speech recognition using the MSP and MPEAK speech coding

strategy with the SMSP and its associated strategy. The SMSP used a filterbank approach with 16 bandpass filters as opposed to 20 bandpass filters with the Spectra 22 processor (SPEAK). An information transmission analysis was performed and most features, such as vowel formant frequencies and consonant manner and place of articulation, were better transmitted using the SMSP processor. For vowels, increased information about formant frequencies and formant transitions, were associated with increased speech recognition scores with the SMSP. Also, results from nonsense syllable tests show few errors in vowel duration, whereas duration was less well perceived for the CNC word tests. The researchers attributed this discrepancy partly to the greater variability in duration caused by surrounding consonants. However, confusions between short vowels and diphthongs were decreased by half when using the SMSP, which was attributed to the perceived differences in duration between short vowels and diphthongs.

Summary

In this study, nine cochlear implant patients from Washington University School of Medicine participated. The subjects responded to CNC words using both the MPEAK and SPEAK speech coding strategies. Their responses were represented in the form of overall word and phoneme scores as well as confusion matrices; to analyze the way each subject and the group perceived the CNC words. Looking at subjects' responses to actual words, as opposed to nonsense syllables, was of key importance. All subjects showed improvement in recognition of words and phonemes in CNC words with the SPEAK strategy. In addition, there was a substantial improvement in initial consonant and medial vowel recognition in words as compared with identification of these phonemes spoken by the same male talker in nonsense syllables. When phonemes were presented to subjects in actual words they were able to use cues from preceding and succeeding phonemes for identification. The information gained from this type of analysis is invaluable in determining the effectiveness of programming parameters for the cochlear implant speech processor. Analysis of error

patterns from the group indicated what information was being conveyed through each processor speech coding strategy. Assessment of individual subjects' performance on CNC word tests indicated which phonemes are troublesome for each individual. An understanding of why these phonemes were troublesome was deduced from the acoustic cues and associated electrical stimulation patterns for the target phoneme and response errors using MPEAK and SPEAK. The information can provide the clinician clues about each individual's implant program parameters that are and are not being used to their maximum potential.

The initial consonants showed the most improvement with the SPEAK speech coding strategy. Identification of all of the stops, nasals, and laterals improved with SPEAK compared with MPEAK for the group. Each individual identified the initial consonants better than any other phoneme, though individual error patterns were varied. Some reasons why subjects performed better with SPEAK include better stop consonant burst information, better F2 formant transition information, and better place of articulation information. Subjects performed better with MPEAK because the F1 information was represented on six to eight electrodes compared to four electrodes with SPEAK. As shown by Skinner et al (in press), assignment of more electrodes to F1 frequencies was associated with improved performance with SPEAK. Stimulation of the high-frequency band electrodes with MPEAK (which is not available with SPEAK) helped with the identification of some consonants (e.g., /t/).

As a group, subjects performed better overall using the SPEAK strategy for identifying medial vowels. With SPEAK, vowels of similar place and different duration were often confused. A reason for the confusions of duration is that medial vowel duration is affected by the preceding and succeeding phonemes; thus, the same phoneme can have a different duration depending on its context. Most vowel errors with MPEAK were the result of poor representation of F2 information. F1 information was better conveyed through the MPEAK strategy because more electrodes are allocated to the frequency range of F1 with MPEAK. Subjects were better able to identify diphthongs using the SPEAK strategy. Better formant

transition information both within diphthongs and between preceding and succeeding consonants allowed for increased correct identification with SPEAK.

Subjects had the most difficulty correctly identifying the final consonants. In addition, the final consonants showed the least improvement from MPEAK to SPEAK. The improvements in recognition that occurred with SPEAK were the result of better representation of burst frequency information for stops, as with the initial consonants, and more formant transition information from the preceding vowel. Many errors for the final consonants were "no response"; that is, the subject did not hear the final consonant. The large number of "no responses" was unique to the final consonants. A number of final consonants contain little energy to begin with and when they were in the final position, their energy was reduced even more. Consequently, there may have been little or no electrical stimulation. Further analysis will indicate whether this assumption is true. As with the initial consonants, many final consonant fricatives were perceived better with MPEAK because of the three high frequency band electrodes, which were not present with SPEAK.

For phonemes in all three positions in CNC words, SPEAK conveyed more information and was associated with more accurate speech recognition than with MPEAK. This improvement was due to better representation of second formant frequencies (and their transitions) and stop consonant burst energy. Greater improvement could have been realized if more than four electrodes had been assigned to the first formant frequency region with SPEAK. The analysis of error responses for the group and individual subjects revealed important patterns of speech recognition with the MPEAK and SPEAK speech coding strategies. These analyses will serve as the basis for further study of the acoustic and associated electrical stimulation patterns from individual subjects' speech processor programs. This future work should provide even greater insight into ways in which individual subjects' speech processor programs may be modified to obtain better speech recognition.

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Appendix A

MPEAK- Raw Scores- Subject 1

Initial Consonants

	RESPONSE																									
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W		WH	Y	L	R	-	
P	4		1		1	1										3	1						1	1	13	
B		6		1				3	1															1	1	13
T			8		4																				12	
D				4		3	1												1						12	
K					7								1												13	
G						1										1	1	1							9	
F							2					2													9	
V																1								1	4	
TU																1								1	3	
TV																									2	
S												10		2											12	
Z																									1	
SH													2	2	2									1	7	
CH														2											5	
J															6										6	
H																4	1								12	
M																									11	
N																		1							9	
W																									11	
WH																									3	
Y																									3	
L																									15	
R																									15	
	11	18	16	11	16	10	12	1	0	0	15	0	4	5	6	10	4	6	4	0	7	11	30	3	38.5%	

Vowels

		RESPONSE																							
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO	-					
Eve	EE	16	1																		1				18
It	I	4	7	2	1				3				4												21
Met	E			3	3		1	1			3	1	1	1											14
Have	A			4	11					1													2		20
S Heart	AR				1																		2		4
T Dog	O																								1
I Corn	OR	1			3			1																	6
M Foot	OO		1							1	2												1		6
U Boot	UU	1									6														10
L Up	U				1			2			10				2								1		18
U Bird	ER			1			1			1	1	4			1	1	1						1		11
S Say	EI	3		3																				2	20
Go	OH		1	1			1				1	1		13											15
I	AI				2						1														14
Out	OW			1																					5
Boy	OI																								2
More	AO				1			1															2		15
		25	10	15	23	0	3	7	4	9	17	7	19	13	14	6	3	24	1						53.5%

Final Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER	-	
P	2																								11
B																									5
T			8		1																				20
D				1																				1	14
K					2			1							2										18
G						1																			8
F							1																	1	7
V								1																	5
TU									1																6
TV										1															2
S											8														12
Z																									7
SH																									4
ZH																									1
CH																3	1								5
J																	3								4
M																									4
N																									12
NG																									21
L																									4
R																									21
ER																									0
	2	0	50	17	6	2	1	2	2	1	12	6	1	0	6	7	7	27	5	10	0	28	8	41.5%	

MPEAK- % Scores- Subject 1

Initial Consonants

	RESPONSE																									
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R		
P	31		8		8	8										23	8					8		8	7	
B		46		8			23	8																8	8	7
T			67		33																				6	
D				33		25	8												8						6	
K	15		23		54								8												7	
G	22			44		11											11	11							5	
F	11	11		11	11		22				22					11									5	
V		25			25			0											25				25		2	
TU	33								0							33								25	2	
TV						50				0												50			1	
S											83		17												6	
Z												0													1	
SH													29	29	29									14	4	
CH			60											40											3	
J															100										3	
H	8				17		33									33	8								6	
M		27															0	9						27	36	6
N						11												22					33	11	22	5
W		9				9													9						64	6
WH			33				33													33	0					2
Y						33																	67			2
L		20		7		7																	13	27	20	8
R							7																	13	80	8
	6	9	8	6	8	5	6	1			8		2	3	3	5	2	3	2		4	6	15	2	38.5%	

Vowels

	RESPONSE																								
	EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW		OI	AO							
Eve	EE	89	6									6													9
It	I	19	33	10	5			14				19													11
Met	E			21	21		7	7			21	7	7												7
Have	A			20	55			5			5				5								10		10
Heart	AR				25	0		25															50		2
Dog	O						0								100										1
Corn	OR	17			50			17								17									3
Foot	OO		17						17	33		17										17			3
Boot	UU	10								60													10		5
Up	U				6			11			56			6	6	6						6	6		9
Bird	ER			9			9			9	9	36		9									18		6
Say	EI	15		15									65												10
Go	OH		7	7			7				7	7		47		7							13		8
I	AI				14						7											71		7	7
Out	OW			20											20							60			3
Boy	OI																						100		1
More	AO				7			7																87	8
		13	5	8	12		2	4	2	5	9	4	10	7	7	3	2	12	1						53.5%

Final Consonants

	RESPONSE																									
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER			
P	18		73		9																				6	
B		0		20																					3	
T			90												5									5	10	
D				7	64			7								7									7	
K						11									11										9	
G							13																	13	4	
F								14																14	4	
V									20	14														20	20	3
TU																								20	20	3
TV											0														17	3
S												67														1
Z																										6
SH													71													4
ZH														25												2
CH															0											1
J																60	20									3
M																	75									2
N																		25	33	8	8					6
NG																		5	62	14	14					11
L																		50	25	0						2
R																										11
ER																										NP
																										7
	1		25	9	3	1	1	1	1	1	1	6	3	1	3	4	4	14	3	5					41.5%	

SPEAK- Raw Scores- Subject 1

Initial Consonants

		RESPONSE																								
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-	
P	5					3	1		1								2									12
B		11			1			2																		14
T	3		5		3			1																		12
D		2		8		1	1																			12
K	2				10									1												13
G				5	1	2																				8
F		1		1				6									1									9
V								2	2																	4
TU								1																		1
TV		1									1															2
S						1						7		5	1											14
Z																										0
SH														7												8
CH															6	1										7
J					1										1	5										7
H					2	2	1	2										1								12
M		2										1						2	2					1	4	12
N						1				1	1								2	2				2	1	10
W																										9
WH	1				1			1																8	1	3
Y												1														2
L								2															7	4		15
R		1						1											1		1			2	9	14
		11	20	5	18	20	11	16	3	1	4	10	0	12	9	6	6	6	2	1	0	0	12	26	1	48.0%

Vowels

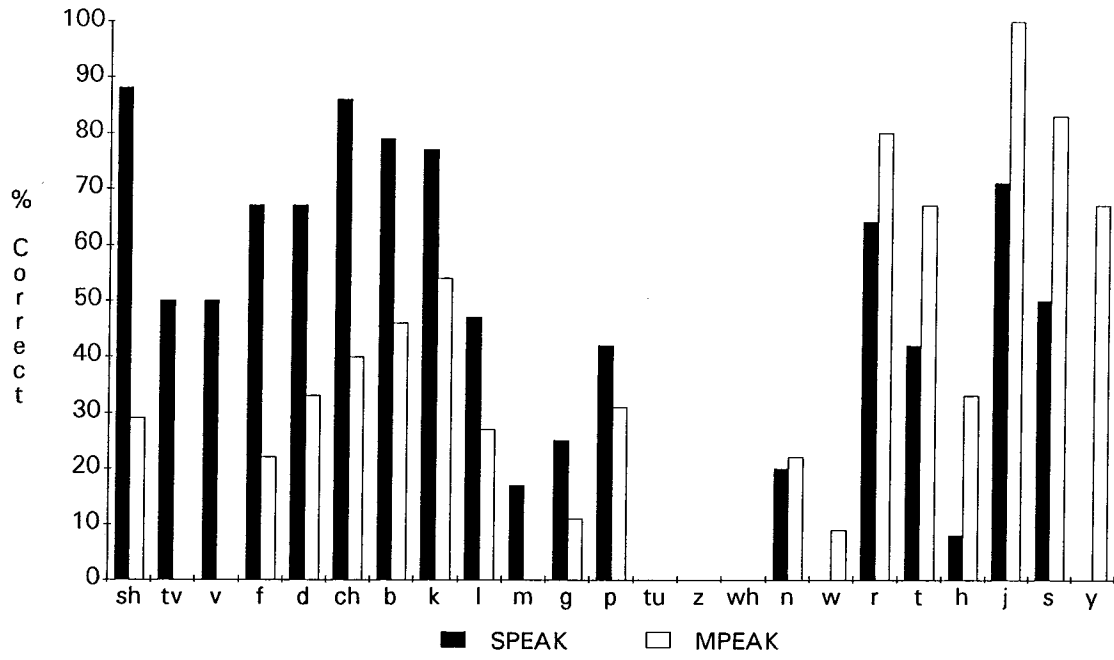
		RESPONSE																		
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-	
Eve	EE	13		1										2						16
It	I	1	16	2					1	1					1				22	
Met	E	2	1	11								2							16	
Have	A		1	6	8			1				1	2		1			2	22	
Heart	AR					1		3						1					5	
Dog	O						1	1										1	3	
Corn	OR							1			1							2	4	
Foot	OO								2	1									3	
Boot	UU	1								6				4				1	12	
Up	U						1		2	1	8			1				4	17	
Bird	ER									1	4	2		2				2	11	
Say	EI	1											17						18	
Go	OH						1							12				2	15	
I	AI							2			2		2		6		3	15		
Out	OW										1			1		1		3	6	
Boy	OI																3	3	3	
More	AO	1						1	1		1			3				5	12	
		19	18	20	8	1	3	9	6	10	17	5	23	25	7	1	6	22	0	56.0%

Final Consonants

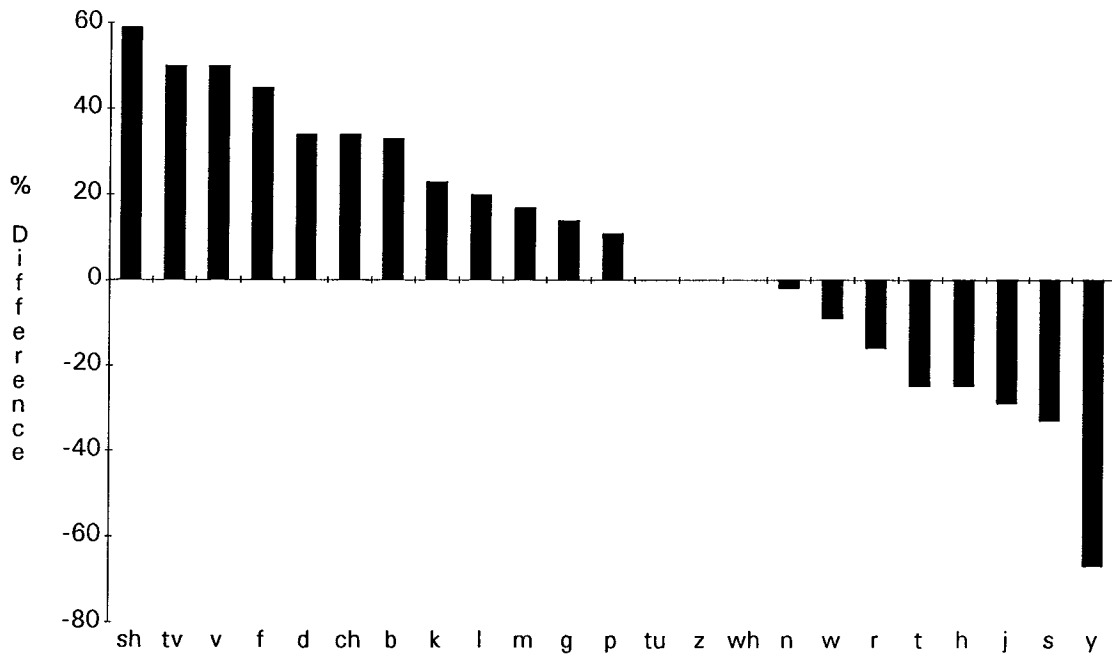
		RESPONSE																							
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER	-	
P	3			2	2	3																		1	12
B		1			3																			1	5
T	1			18	1	1	1									1									23
D					12			2													2				16
K				9		6	1																		16
G	1				5		1														1				8
F				2		3																		1	6
V					1					1															7
TU				3																					4
TV																									1
S												8													11
Z																									8
SH																									4
ZH						1																			0
CH							2										4	1							7
J																		4							4
M																									4
N																			1	1		2	3	2	10
NG				1	4														3	6	1	2	2	2	21
L					2																			1	4
R					2			1																	20
ER						3																			1
		5	2	37	35	16	7	0	1	0	0	9	3	3	1	6	8	6	13	2	20	0	21	5	43.5%

Subject 1

Initial Consonants

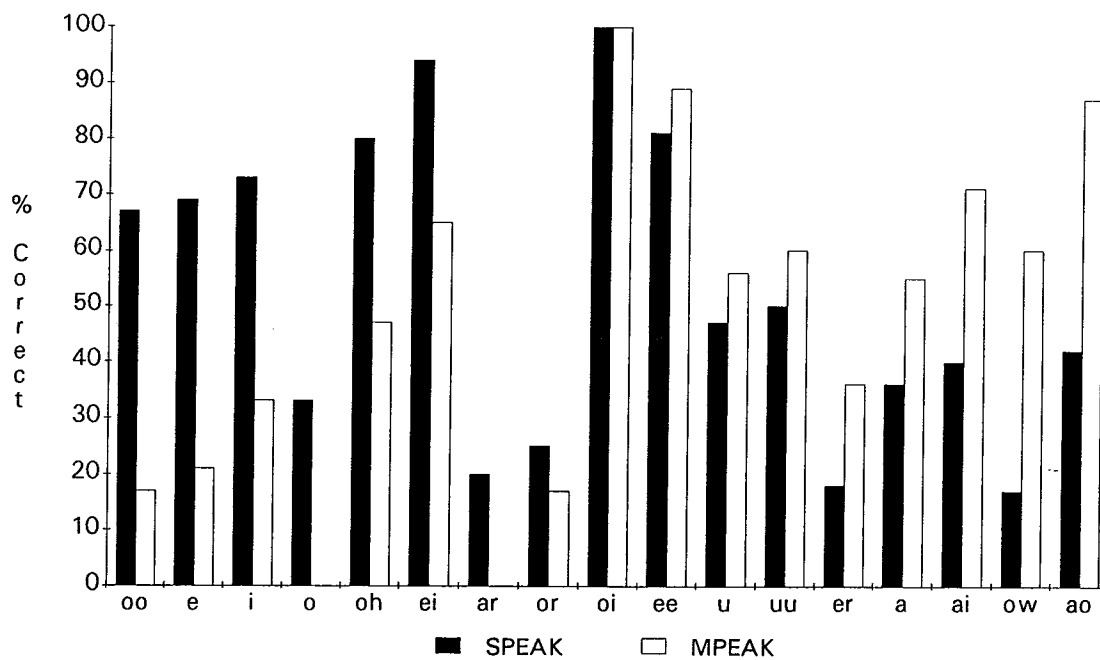


Initial Consonants

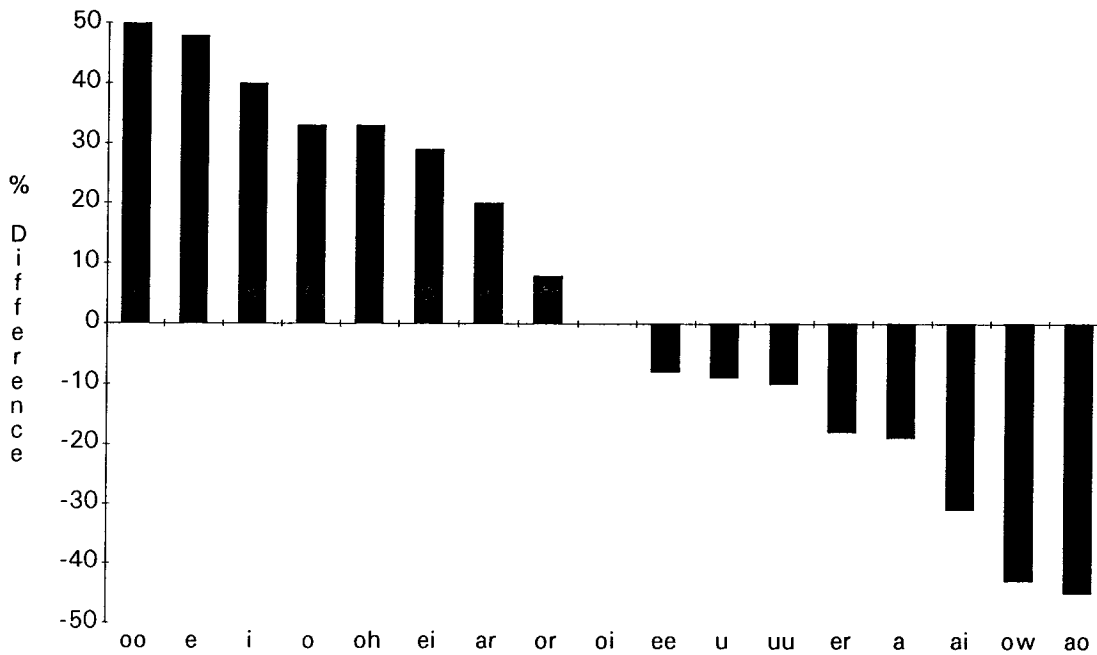


Subject 1

Medial Vowels

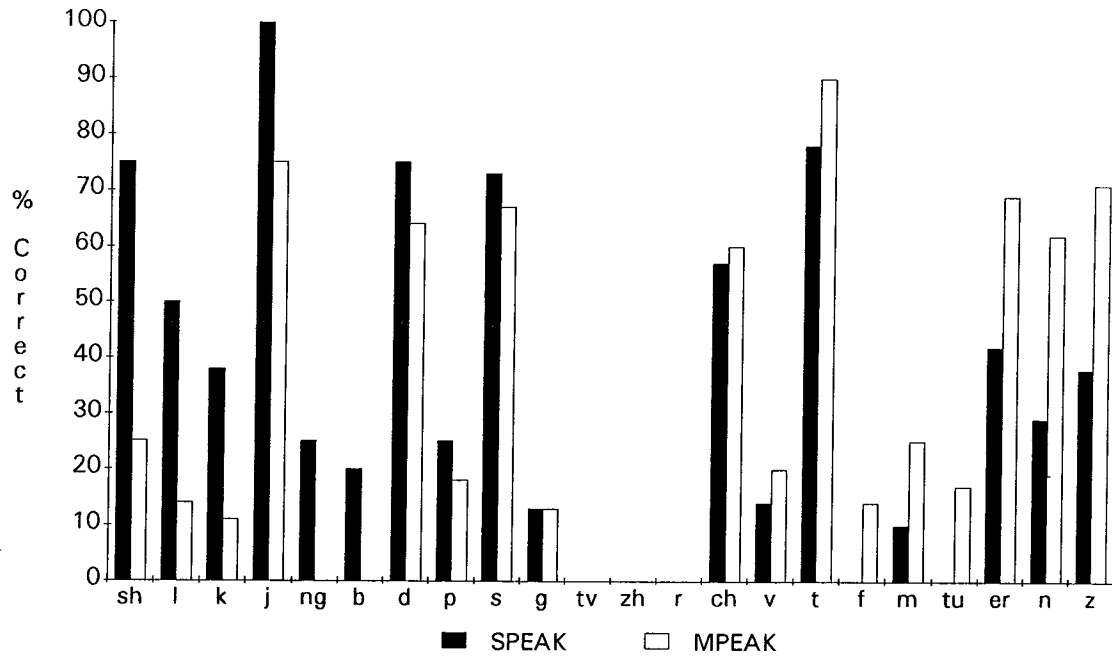


Medial Vowels

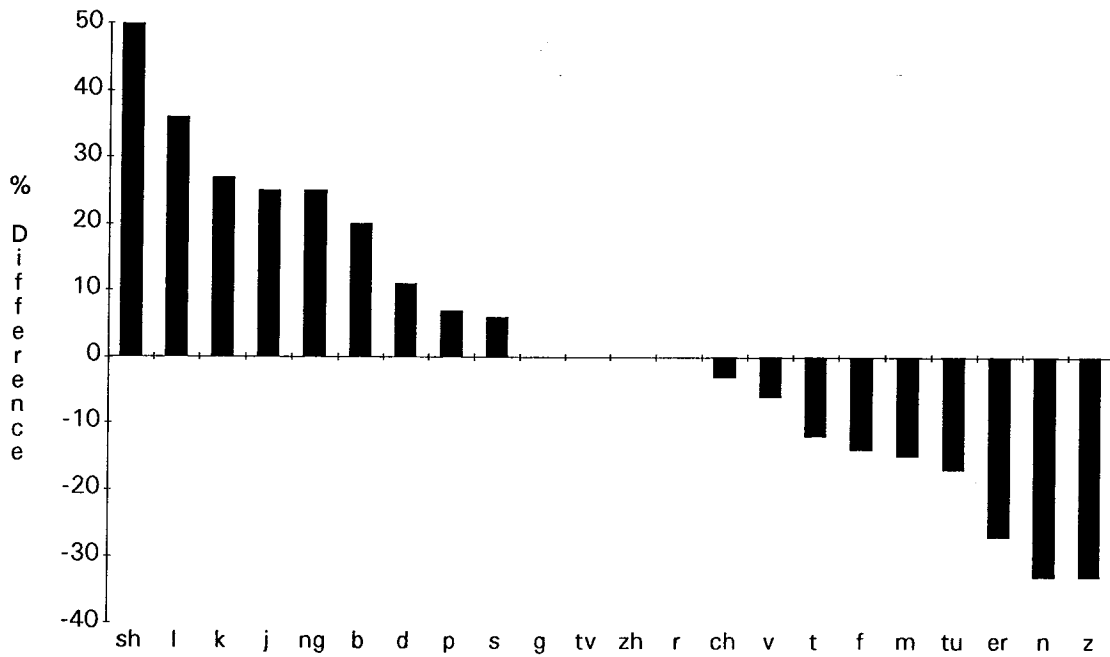


Subject 1

Final Consonants



Final Consonants



MPEAK- Raw Scores- Subject 2

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W		WH	Y	L	R	-
P	5		4			1										1						1		1	13
B		12				1		1																	14
T			9	1	2																				12
D		1		11																					12
K			2		11																				13
G		1		3		3		1																	8
F							6				1					2									9
V		2						2																	4
TU									1																1
TV				1													1								1
S										12		1													13
Z																						1			1
SH												6	1												7
CH													6												6
J														6											6
H															11										12
M																	1		1	1					12
N																		3					9		12
W																									9
WH		1																	5					3	9
Y																				1					3
L																						2			3
R																							14		15
																			2				5	8	15
	6	18	15	16	13	5	8	4	1	0	13	0	7	7	7	14	2	4	9	0	3	33	14	1	67.0%

Vowels

		RESPONSE																							
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO						
Eve	EE	15											2												17
It	I		14	3						1			1	1											20
Met	E	1	1	14	1																				17
Have	A	1		2	15								2												20
S Heart	AR				1	1					1												1		4
T Dog	O									1													2		3
I Corn	OR				1						2		1												4
M Foot	OO											4	1												6
U Boot	UU	2								6															10
L Up	U		2	1		2					12				2										17
U Bird	ER											1												1	11
S Say	EI	1		1									6	2			1							1	20
Go	OH			1																					14
I	AI			1																			2		15
Out	OW			1																					5
Boy	OI																							3	3
More	AO																								14
		20	18	24	18	3	1	3	1	6	8	17	6	25	15	15	5	5	11	0					72.0%

Final Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER	-	
P	7		3						1																11
B		5																							5
T			22																						22
D		1		12		2																			15
K	2		5		10																				17
G						8																			8
F							6																		6
V								4																	5
TU	1		2				1		1												1				5
TV		1																							2
S											10														10
Z												8													8
SH														4											4
ZH																									1
CH																7									7
J																	4								4
M																		7	1						11
N																		2	10		2			1	21
NG			1		1			2										1	1	1					4
L																					16		3	1	21
R																									1
ER																									12
	10	7	33	13	10	10	7	8	2	0	11	8	4	0	7	4	10	12	1	28	0	13	2	74.0%	

SPEAK- % Scores- Subject 2

Initial Consonants

	RESPONSE																									
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W		WH	Y	L	R		
P	62		8		8											23									7	
B		92																							6	
T			82		18																				6	
D				8	67		17																		6	
K					15		85																		7	
G						11		89																	5	
F							100																		5	
V								33	33																2	
TU									25	25															2	
TV										100															1	
S											79			21											7	
Z															100										NP	
SH																100								4		
CH																	100							3		
J																		100						4		
H																			67					6		
M																				27				6		
N																					56			5		
W																						9	8	6		
WH																						9	45	6		
Y																							11	33	5	
L																							10	30	5	
R																								94	6	8
																								33	53	8
	4	7	7	5	8	6	6	1	1	6	5	3	4	6	2	3	5	3	15	6	1	73.5%				

Vowels

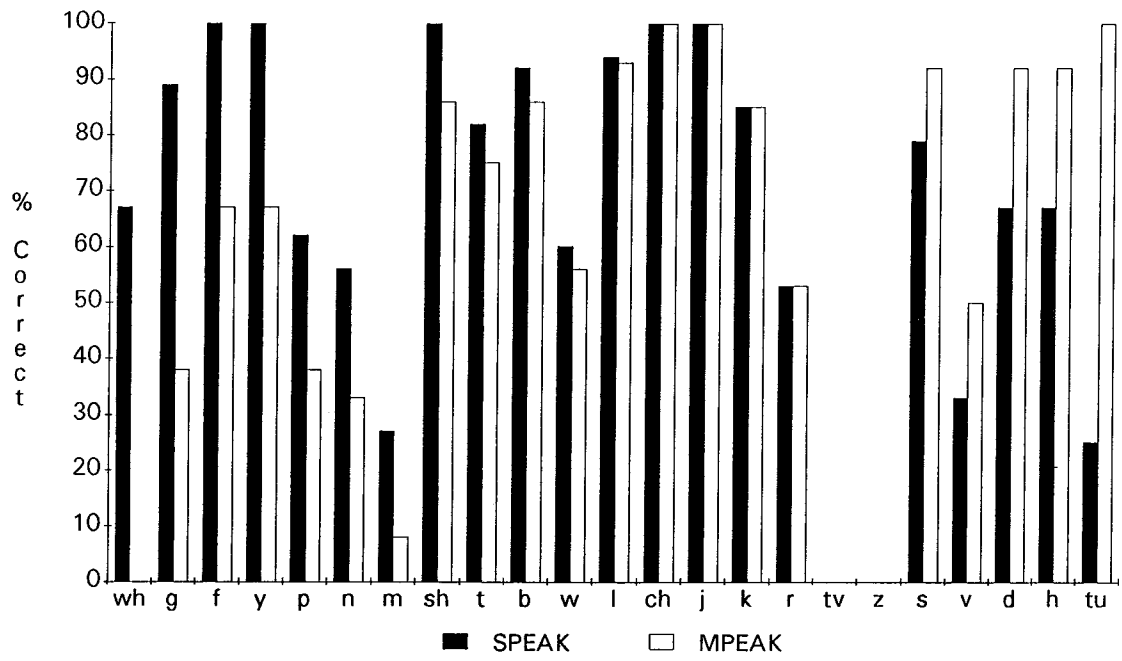
		RESPONSE																						
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH		AI	OW	OI	AO					
Eve	EE	71											29											9
It	I	13	70	9									9											12
Met	E			86	7								7											7
Have	A				10	86							5											11
S Heart	AR						67	17								17								3
T Dog	O							0														100		1
I Corn	OR								20													20		3
M Foot	OO									100														1
U Boot	UU										8	67	8											6
L Up	U												67		17								22	9
U Bird	ER																						27	6
S Say	EI												55											9
Go	OH													100										9
I	AI														93								7	8
Out	OW															100								7
Boy	OI																							3
More	AO																							2
																								7
		8	9	9	11	3	1	1	2	4	7	3	14	9	8	2	2	12						78.5%

Final Consonants

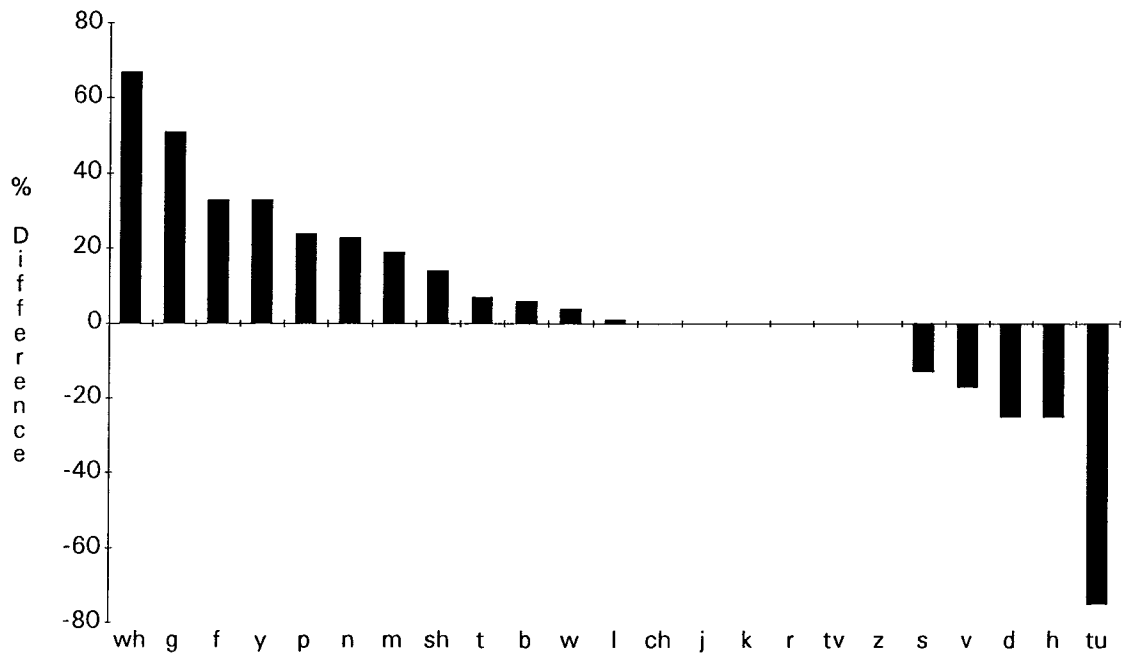
	RESPONSE																							
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER	
P	73		18		9																			6
B		100																						3
T			91		9																			11
D				20	73					7														8
K					17		78																	9
G						14	14		71															4
F								17		83														3
V									33		67													3
TU																								3
TV																								1
S												100												7
Z																								3
SH																								2
ZH																								NP
CH																								3
J																								2
M																								6
N																								6
NG																								11
L																								2
R																								11
ER																								7
	5	5	16	12	10	3	3	5	1	7	3	2	3	3	1	4	14	7	1	69.5%				

Subject 2

Initial Consonants

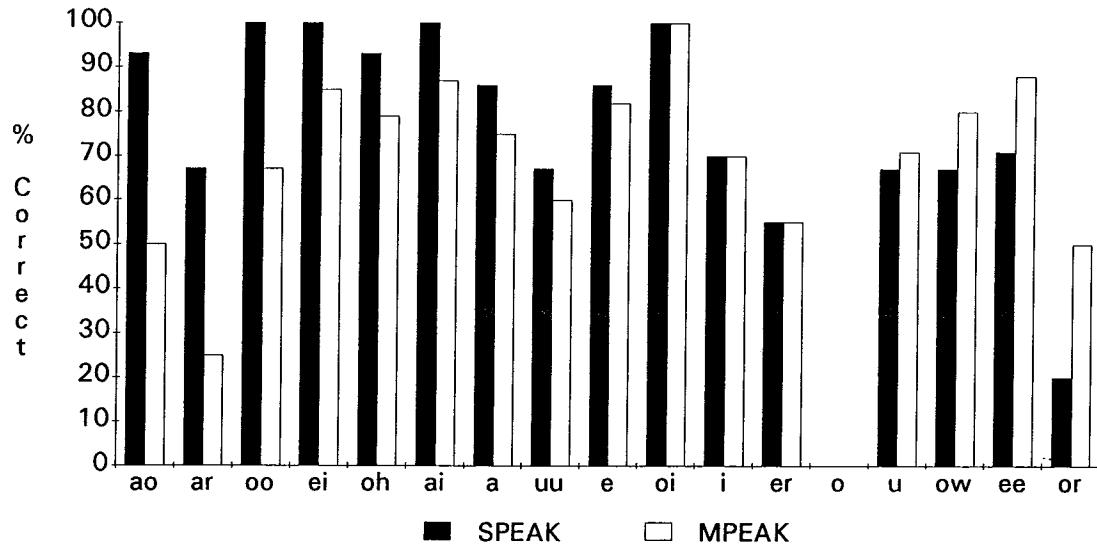


Initial Consonants

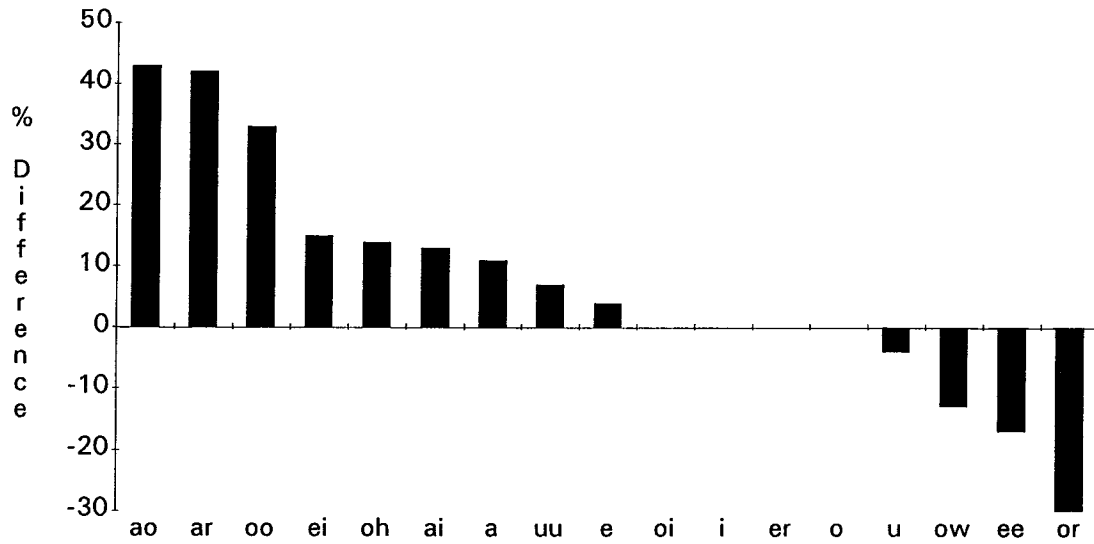


Subject 2

Medial Vowels

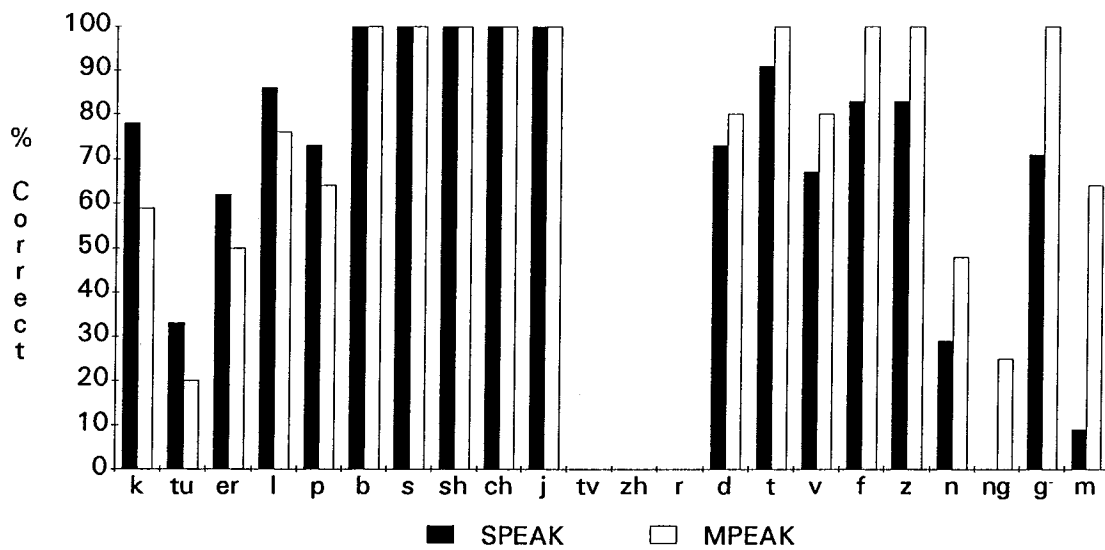


Medial Vowels

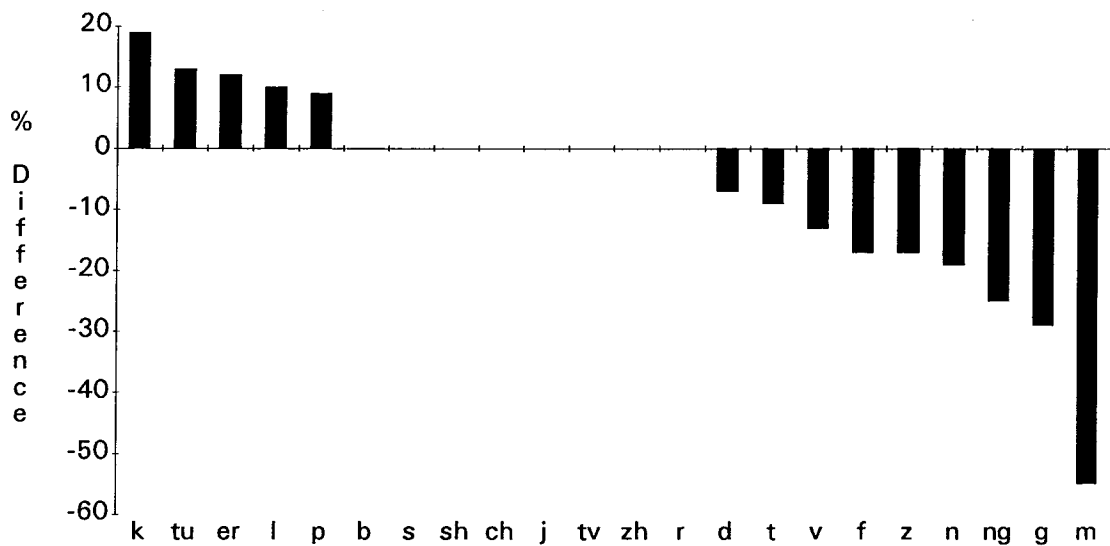


Subject 2

Final Consonants



Final Consonants



MPEAK- Raw Scores- Subject 3

Initial Consonants

RESPONSE

	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-		
P		3	2		3											2			2					2	14	
B		6		2	1	2																		1	12	
T	1		4	1	4																			1	11	
D		3		3	1																		1	1	12	
K	1	1	2		6				1							2									13	
G	1	3		3		1		1							1									1	9	
F		2				1	1				1					1								1	9	
V		1	1			1																		1	3	
TU				1			1																	1	3	
TV															1										1	
S		1									11			1											13	
Z																									0	
SH											1		4			1								1	7	
CH		2												4											6	
J				1	1									2	2									1	7	
H		5	1	2		1								1	1								1	1	12	
M	1	2				1		1								1	3						1	1	11	
N		1		1		1												1	3						8	
W		1	1																	5			2	1	1	11
WH	1	1					1																	1	4	
Y						1													1						1	3
L	1	2	1	1	1	1									2	1							2	2	15	
R	1	2	1		1										1	1	2			1			1	4	2	16
	7	36	13	15	18	10	3	1	1	0	13	0	4	7	8	9	6	4	8	0	0	0	7	12	18	29.5%

Vowels

RESPONSE

	EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-	
Eve	EE	13	2		1													1	17
It	I	1	10	2				1		1		3					1	3	22
Met	E			2	1	1	1				2	2					1	3	14
Have	A	1		3	10		1					2				1	2	20	
Heart	AR				1	2		1										5	
Dog	O																1	1	
Corn	OR		1		1									1	1		1	5	
Foot	OO							2	1								1	4	
Boot	UU	1	1		1			1	1	1			1				1	2	10
Up	U		1	1	1		1	1		2	1	1	3		1		3	1	17
Bird	ER		1	1	1			2	1	1		1		1	1		1	2	12
Say	EI		1	2	2	1				1		8		1				3	19
Go	OH				1	1		2		1		2	4				4	15	
I	AI		1	2	2		1	1	1	1	2	1	2			1	1	15	
Out	OW						1			1					3		1	6	
Boy	OI															3		3	
More	AO					1	1		1	2		1			2	2	2	3	15
		16	18	13	22	6	3	7	7	3	12	4	20	11	4	8	8	19	32.0%

Final Consonants

RESPONSE

	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER	-	
P				1	3	1	1														2		1	11
B		1																1	1		1		1	5
T	1		12	1	4	2																	1	21
D				3	1	2							1								6		1	15
K			4	2	6	1															1		4	18
G				4	1																			7
F	1		1		1		2				1										2			6
V			1	2													1							5
TU			1	1	2																		2	7
TV																					1			1
S			2	1							7												3	13
Z							1																	6
SH													5											4
ZH													2	1										4
CH						1							1											1
J		1													2								1	5
M				1											1								1	4
N		1		1												1						2	2	11
NG	1										1						2	3			2		2	4
L			1	2																	1		1	4
R																						2	2	21
ER			1					1														2	3	0
	5	1	25	19	18	7	4	1	0	0	9	9	1	0	3	2	6	25	3	29	0	9	24	33.5%

MPEAK- % Scores- Subject 3

Initial Consonants

	RESPONSE																			-					
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W			WH	Y	L	R
P	0	21	14		21										14				14					14	7
B		50		17	8	17																		8	6
T	9		36	9	36																		9	6	
D		25		25	8																	8	8	25	6
K	8	8	15		46			8							15									7	
G	11	33		33		11							11											5	
F		22			11	11				11					11								11	22	5
V		33	33		33		0																	33	2
TU				33			33		0																2
TV										0				100											1
S		8								85		8													7
Z																									NP
SH										14		57			14									14	4
CH		33										67													3
J				14	14							29	29											14	4
H		42	8	17		8						8	0		0								8	8	6
M	9	18				9		9						9	27							9	9		6
N		13		13		13									13	38								13	4
W		9	9															45				18	9	9	6
WH	25	25					25												0				25		2
Y					33																33				2
L	7	13	7	7	7	7							13	7				7				13	13		8
R	6	13	6		6								6	6	13							6	25	13	8
	4	18	7	8	9	5	2	1	1		7		2	4	4	5	3	2	4			4	6	9	29.5%

Vowels

		RESPONSE																-								
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW	OI			AO						
Eve	EE	76	12		6																			6	9	
It	I	5	45	9					5		5		14										5	14	11	
Met	E			14	7	7	7	7			14		14										7	21	7	
Have	A	5		15	50		5						10									5	10		10	
S Heart	AR				20	40		20															20		3	
T Dog	O						0																	100	1	
I Corn	OR		20		20			0							20	20								20	3	
M Foot	OO								50	25														25	2	
U Boot	UU	10	10		10				10	10	10			10									10	20	5	
L Up	U		6	6	6			6	6	12	6	6	18		6		18	6					18	6	9	
U Bird	ER		8	8	8				17	8	8	0		8		8		8					8	17	6	
S Say	EI		5	11	11	5					5		42		5									16	10	
Go	OH			7	7			13			7		13	27										27	8	
I	AI		7	13	13			7			7	7	13	7	13								7		8	
Out	OW							17																50	17	3
Boy	OI																							100		2
More	AO					7	7				7	13		7									13	13	20	8
		8	9	7	11	3	2	4	4	2	6	2	10	6	2	4	4	10	10							32.0%

Final Consonants

	RESPONSE																			-						
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG			L	R	ER		
P	18			9	27	9	9													18				9	6	
B		20																20	20		20			20	3	
T	5		57	5	19	10																	5	11		
D				20	7	13				7									40		7		7	8		
K			22	11	33	6																		9		
G				57	14	0													29					4		
F	17		17		17		33			17														3		
V			20	40				0								20				20				3		
TU			14	14	29				0											14				4		
TV										0														29	4	
S											54														1	
Z			15	8																				23	7	
SH							17																		3	
ZH											83														2	
CH			20			20					50	25			25										1	
J					25						100			0		25								20	3	
M				9	9										0	25								25	2	
N	5									5						18	27			18			18		6	
NG																50		41	9	14			9	18	11	
L			5	10															0	25				25	2	
R																			5	62			10	10	11	
ER			8					8																		NP
	3	1	13	10	9	4	2	1		5	5	1		2	1	3	13	2	15				5	12	33.5%	

SPEAK- Raw Scores- Subject 3

Initial Consonants

	RESPONSE																			-						
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W			WH	Y	L	R	
P	5				1	1									1									4	12	
B	1	5				1				1								1					3	3	15	
T		1	5	1	2																			2	12	
D			2	7											2									1	12	
K	1			1	12																			1	14	
G		1				3			1															3	8	
F				1	1													1	1					2	8	
V		1					1									1	1		1					2	4	
TU				1																					1	1
TV	1	1															1								3	3
S		1	1							4		1	4									1	1		13	1
Z											1					1								1	7	7
SH			2									1	3									1		1	1	6
CH			2																						2	12
J				1		2								1											1	10
H		1			2										8										2	12
M		2							1							4	1	1	1						2	10
N		1														1	2					3	1	1	1	9
W		1																8							1	3
WH																			1				1			2
Y																					1					15
L	1	2			1	1												3	1			3	3	2	14	14
R			1															2				1	8		26	40.5%
	9	19	11	12	17	10	2	0	0	2	7	0	3	7	1	16	8	9	14	1	1	13	12	26		

Vowels

		RESPONSE													-										
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH			AI	OW	OI	AO					
Eve	EE	6	5	1	1						1	2											1	17	
It	I	2	7		1				1		3	2	1			1							3	21	
Met	E			6	2						1	2	1										4	16	
Have	A		1	4	7		1	1			1	1	2	1									2	21	
S Heart	AR				1									1									1	3	
T Dog	O					1	1																1	2	
I Corn	OR				1			1	1															2	5
M Foot	OO	1								1													1	2	5
U Boot	UU		1							1	2			1	3								3	11	
L Up	U		1		2		1	1	4		3		2	1								2	3	17	
U Bird	ER			1			1		1		2	5		1										2	11
S Say	EI	2	1	2	2	1							8										3	19	
Go	OH							1	1	1				3								1	6	1	14
I	AI			1	1	1					1	4	1		2	2						1	1	1	15
Out	OW			1	1									1		1							2	2	6
Boy	OI										1												1	1	2
More	AO		1	1	1		1				1			2		1						6	1	1	15
		11	17	17	20	2	5	5	10	4	11	14	17	15	3	5	1	18	25				25	29.0%	

Final Consonants

	RESPONSE																			-						
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG			L	R	ER		
P	1				7																			1	11	
B		1		1	1												1				1			1	6	
T	1		6		6	1								2										6	22	
D			1	8					1										1	1	1		1	2	15	
K	1		1		9	1				1									1					3	17	
G					1	2										1					1			2	8	
F	1				2	1	1																1	1	7	
V				1																				1	1	6
TU					1			1																2	4	
TV																									2	4
S											2	1	3		1				1				1	2	2	
Z												4				1			1					1	10	
SH													3											1	8	
ZH														3											1	4
CH				1		1								5											0	
J					1											3									7	
M	1				1			1									1	1	1	2			1	4		
N	1				2							1						8	1	3			3	3	10	
NG					1	1													2					3	21	
L				1																2				4	4	
R						2											2	1		11				4	21	
ER					1																		1	1	1	
		6	1	13	15	30	8	2	0	1	0	2	6	6	0	8	5	4	20	5	23	0	11	34	34.5%	

SPEAK- % Scores- Subject 3

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	-
P	42				8	8										8								33	6
B	7	33				7					7													20	8
T		8	42	8	17						8												20	17	6
D		17		58											17									8	6
K	7			7	86																				7
G		13				38				13														38	4
F		13					13										13	13						25	4
V							25	0								25	25		25					25	2
TU				100					0																1
TV	33	33								0							33								2
S		8	8								31		8	31									8	8	7
Z												0													1
SH			29								14		14			100							14	14	4
CH			29										14	43		14								14	4
J				17		33								17										33	3
H		8				17									67									8	6
M		17								8						33	8	8	8					17	6
N		10													10	10	20					30	10	10	5
W		11																	89						5
WH															33				33	0			33		2
Y																					50				1
L	7	13																50				20	20	13	8
R			7		7	7												14				7	57		7
	5	10	6	6	9	5	1			1	4		2	4	1	8	4	5	7		1	7	6	13	40.5%

Vowels

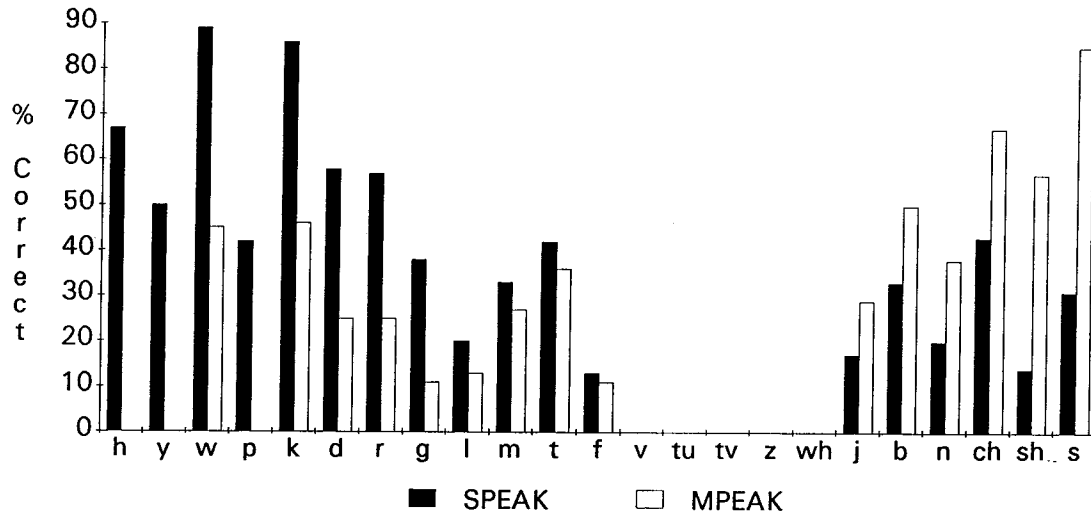
		RESPONSE																						
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO	-				
Eve	EE	35	29	6	6						6	12									6			9
It	I	10	33		5				5	14	10	5			5						14			11
Met	E			38	13						6	13	6								25			8
Have	A		5	19	33		5	5		5	5	10	5								10			11
S Heart	AR				33	0							33											2
T Dog	O					50	50														33			1
I Corn	OR				20			20	20															3
M Foot	OO	20							20													20	40	3
U Boot	UU		9						9	18			9	27									27	6
L Up	U		6		12		6	6	24		18		12	6								12		9
U Bird	ER			9			9		9		18	45		9										6
S Say	EI	11	5	11	11	5							42											10
Go	OH							7	7	7				21							7	43	7	7
I	AI			7	7	7					7	27	7		13	13					7	7		8
Out	OW			17	17									17		17							33	3
Boy	OI									50											0	50		1
More	AO		7	7	7		7				7			13		7					40	7		8
		6	9	9	10	1	3	3	5	2	6	7	9	8	2	3	1				9	13		29.0%

Final Consonants

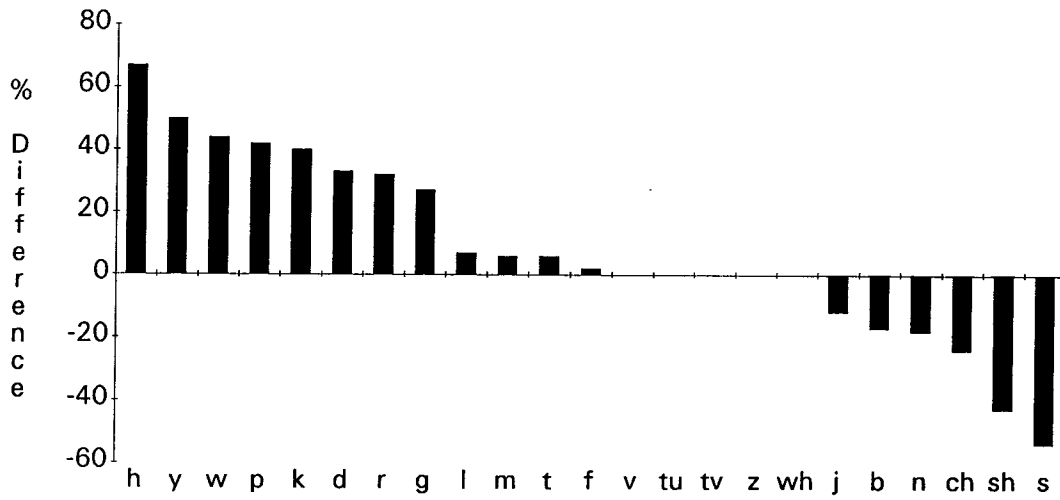
	RESPONSE																							
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER	-
P	9		9		64														9			9		6
B		17		17	17												17			17			17	3
T	5		27		27	5								9									27	11
D			7	53														7	7	7			7	8
K	6				53	6			6									6					18	9
G					13	25										13		13		13			25	4
F	14				29	14	14																14	4
V				17				0										17		17			50	3
TU					25		25		0														50	2
TV										0								50					50	1
S				10							20	10	30		10								20	5
Z				13								50				13		13					13	4
SH													75										25	2
ZH															71									NP
CH				14		14										75								4
J					25																			2
M	10			10		10						10				10	10	10	20			10	5	
N	5			10														38	5	14		14	14	11
NG				25	25													50						2
L				5		10										10	5		52				19	11
R																					0	100		1
ER				8														25		25		17	25	6
	3	1	7	8	15	4	1		1		1	3	3		4	3	2	10	3	12		6	17	34.5%

Subject 3

Initial Consonants

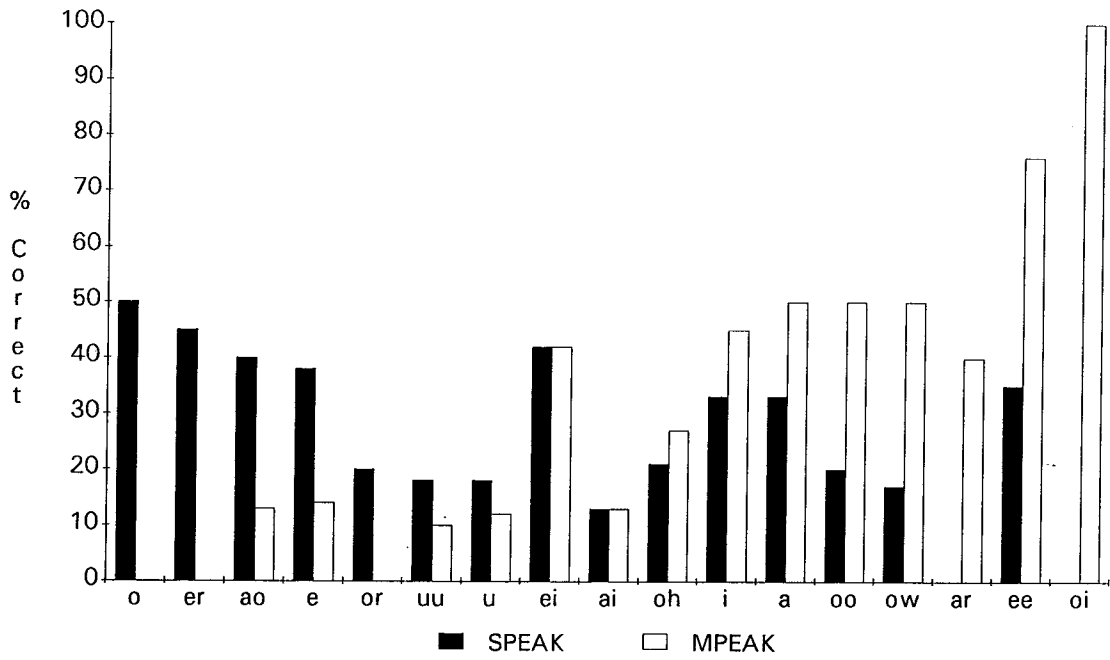


Initial Consonants

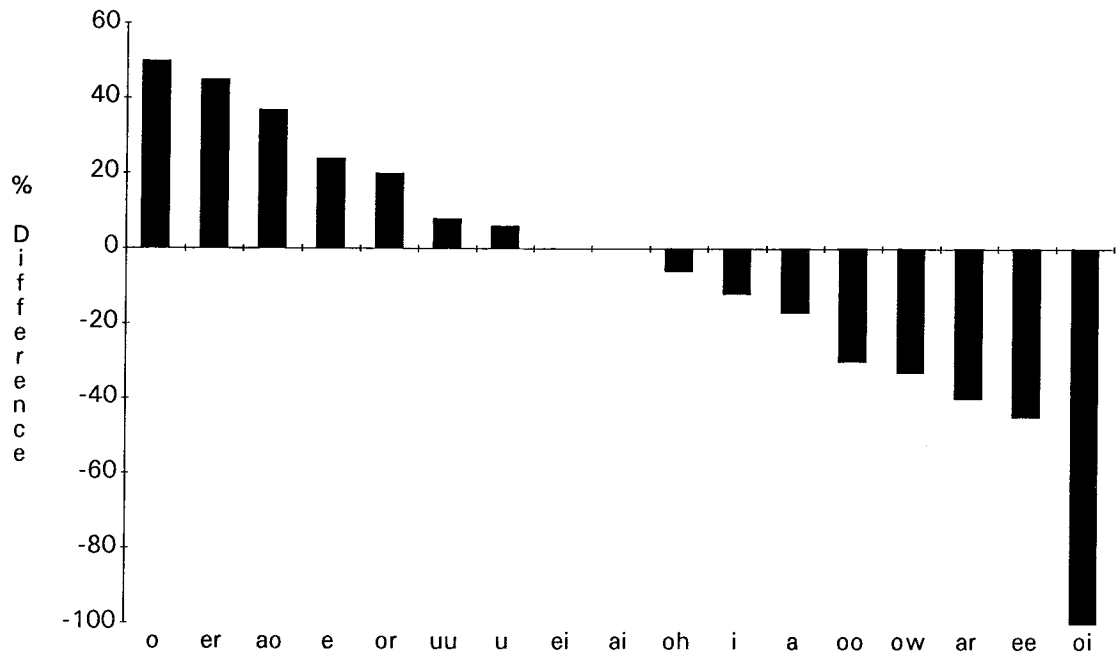


Subject 3

Medial Vowels

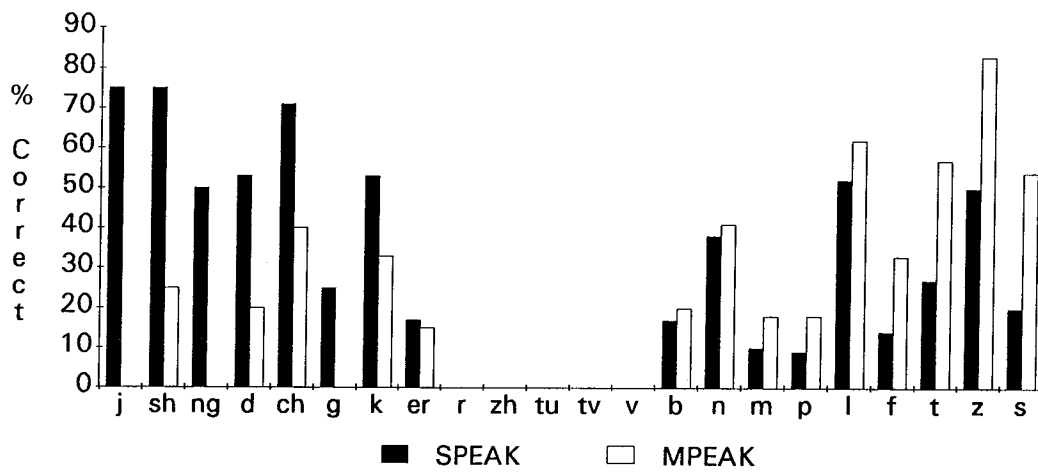


Medial Vowels

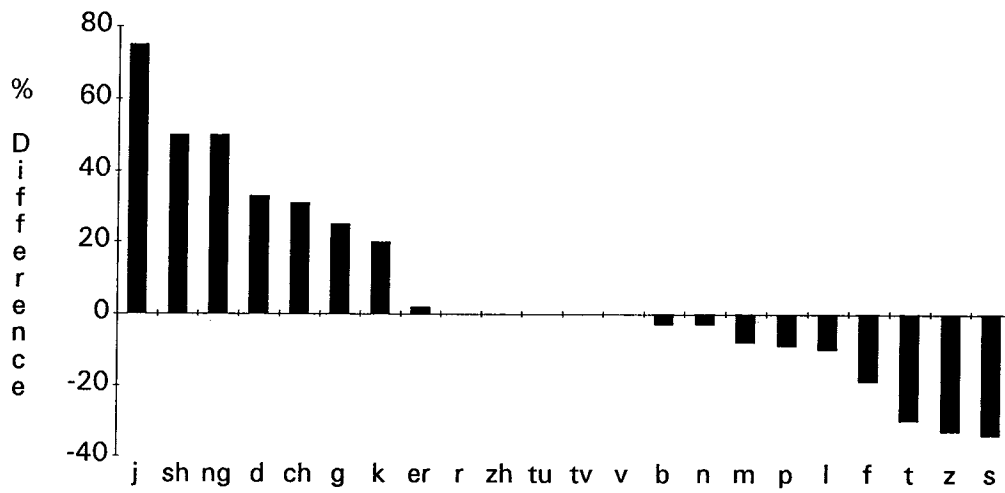


Subject 3

Final Consonants



Final Consonants



MPEAK- Raw Scores- Subject 4

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	WH	Y		L	R		
P	10															1	1						1	13	
B		9			1		2									1				1				14	
T			9	1																				11	
D				12																				12	
K					11																			14	
G						4																		8	
F							7																	8	
V								2		1														3	
TU																								2	
TV																1							1	3	
S													14											14	
Z																								1	
SH														5										6	
CH															6									7	
J																4							1	6	
H																	9							12	
M																		3						12	
N																			2					9	
WH																				2				8	
Y																								3	
L																								3	
R																								16	
																								15	
	18	19	10	17	12	13	9	2	0	1	15	0	5	6	4	12	4	2	19	1	3	4	23	1	65.0%

Vowels

		RESPONSE																							
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW		OI	AO						
Eve	EE	16																							17
It	I		10	1					3	3	2	1	1												21
Met	E			9	1					1	4										1				17
Have	A				2	13					1											2			20
Heart	AR										1														4
Dog	O											1													2
Corn	OR						1	1			2														4
Foot	OO																								4
Boot	UU										3														11
Up	U										2	8													17
Bird	ER										1		12												11
Say	EI											1		5	1	1									19
Go	OH															10									13
I	AI																								15
Out	OW																								6
Boy	OI																								3
More	AO																								16
		19	13	17	16	2	2	5	11	12	24	6	17	11	12	6	3	23	1						63.5%

Final Consonants

		RESPONSE																							
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER	
P		3																							10
B																									6
T																									23
D																									15
K																									18
G																									7
F																									6
V																									5
TU																									5
TV																									2
S																									10
Z																									7
SH																									4
ZH																									0
CH																									8
J																									4
M																									4
N																									10
NG																									21
L																									4
R																									22
ER																									1
																									12
		3	0	29	18	19	8	4	9	1	0	11	7	4	0	8	1	3	21	1	26	2	15	10	62.0%

MPEAK- % Scores- Subject 4

Initial Consonants

	RESPONSE																									
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-		
P	77															8	8								8	7
B		64		7		14										7				7						7
T	9		82	9																						6
D				100																						6
K	14		7		79																					7
G	13			38		50																				4
F		13					88																			4
V								67		33																2
TU	50	50							0																	1
TV		33								0						33							33			2
S											100															7
Z							100					0														1
SH											17		83													3
CH					14									86												4
J						17									67											3
H	25															75							17			6
M		17															25									6
N																		22						8	17	6
W		13																	22							5
WH			67					33												75						4
Y																						0				2
L																							67			2
R																								13	19	8
-																									87	8
	9	10	5	9	6	7	5	1	1	8	3	3	2	6	2	1	10	2	10	2	2	12	1	65.0%		

Vowels

	RESPONSE																				
	EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-			
Eve	EE																		9		
It	I	48	5					14	14	10	5	5						11			
Met	E	6	53	6					6	24								9			
Have	A		10	65						5	10				10			10			
Heart	AR				0	25				25					25		25	2			
Dog	O					50											50	1			
Corn	OR			25	25		50											2			
Foot	OO							75									25	2			
Boot	UU							18	73								9	6			
Up	U		6				6			71							18	9			
Bird	ER							9		9	45	9	9				18	6			
Say	EI	11	5	5	5							63		5			5	10			
Go	OH						8	8					77				8	7			
I	AI		13	7				7		7				67				8			
Out	OW			33						17					33			3			
Boy	OI															100		2			
More	AO				6	6			6					6			75	8			
		10	7	9	8	1	1	3	6	6	12	3	9	6	6	3	2	12	1	63.5%	

Final Consonants

	RESPONSE																							
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER	-	
P	30		40	10	10																10			5
B		0		33													17	17			17			3
T			91	4			4																17	12
D				67		7		7														7	13	8
K			17		78	6																		9
G				29		43		14																4
F					17	17	50		17										14					4
V								60																3
TU		20		40					0											20			20	3
TV										0										20				3
S											100										50			1
Z												100												5
SH													100											4
ZH														100										2
CH															100									NP
J					25	25					25					25								4
M				10													20	20		20		10	20	2
N								10										67		10			14	5
NG			25						25										25	25				11
L						5															64	5	27	2
R																						0	100	11
ER																						8	50	1
-																								8
	2	15	9	10	4	2	5	1	6	4	2	4	1	2	11	1	13	1	13	1	8	5	62.0%	

SPEAK- Raw Scores- Subject 4

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W		WH	Y	L	R	-
P	8	1			2											1									12
B	1	11		1																					13
T			11			1																			12
D		1		10		1																			12
K					13																				13
G				2		6										1									9
F	1	2					5									1									9
V		1					1	1																	4
TU		1							1														1		3
TV		1																							1
S										12			1												13
Z																									0
SH							1			1		6													8
CH												2	4												6
J														7											7
H	4	1	1			2									4										12
M		2														4									11
N				1												2	6					1	1		11
W																		3							10
WH															1			7					4		11
Y																			2						3
L				1																2					2
R																4		3	2			5			15
-	14	21	12	15	15	8	10	1	1	0	13	0	9	4	7	8	11	6	15	3	2	7	18	0	67.5%

Vowels

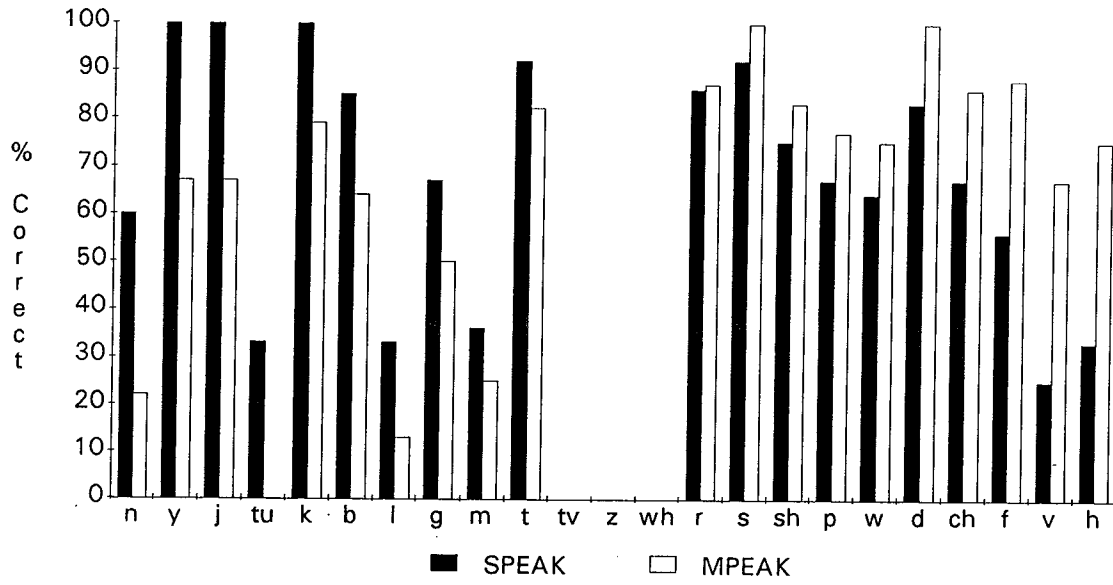
		RESPONSE																							
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO						
Eve	EE	17																							17
It	I	3	19						1																23
Met	E			9					1		2		1												13
Have	A			1	13	1					1	1	3			2									22
S Heart	AR					3																	2		5
T Dog	O						1																	2	1
I Corn	OR					1			3																6
M Foot	OO									3															3
U Boot	UU										10			1										1	12
L Up	U		1	1						2		11		3											18
U Bird	ER									2			8											1	11
S Say	EI			1										17											18
Go	OH										2														16
I	AI					1									1	13								1	14
Out	OW																8	1	1				2		6
Boy	OI															2		3						1	2
More	AO					1					1												2		6
-		20	20	12	13	7	1	3	10	12	14	9	22	19	10	4	3	21	0						75.0%

Final Consonants

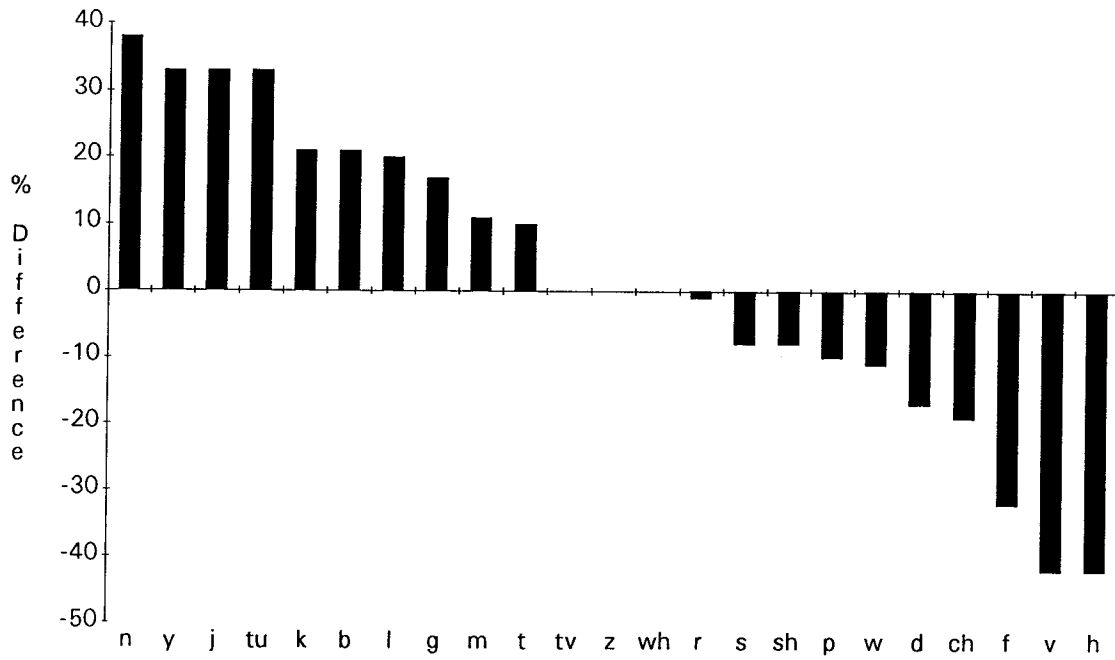
	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER	-	
P	5		2		4																			1	12
B		3			1																				5
T	2		17		2																		1		21
D			1	8		1															1		1	3	15
K			3		14																				17
G	1			1	1	5																			8
F		1	4		2																				7
V								3																	7
TU			1	1	1																2		2		7
TV									1															2	5
S											12		1												1
Z											1	6													13
SH													3		1										7
ZH																									4
CH															5										0
J																2					1				4
M																	2								4
N			1															4			6		2		11
NG						1		2											4		4		6	4	21
L																			3	1					4
R																				16		3	1		20
ER																									0
-	8	4	29	11	25	7	0	6	0	0	13	6	4	0	6	2	2	4	3	34	0	23	13	59.0%	

Subject 4

Initial Consonants

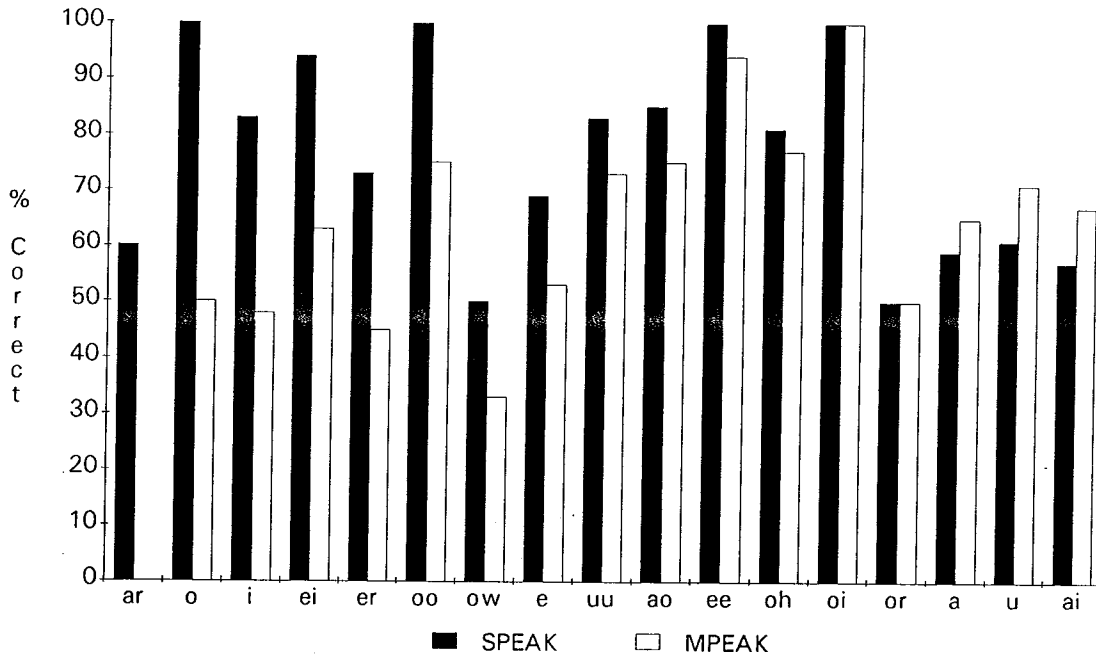


Initial Consonants

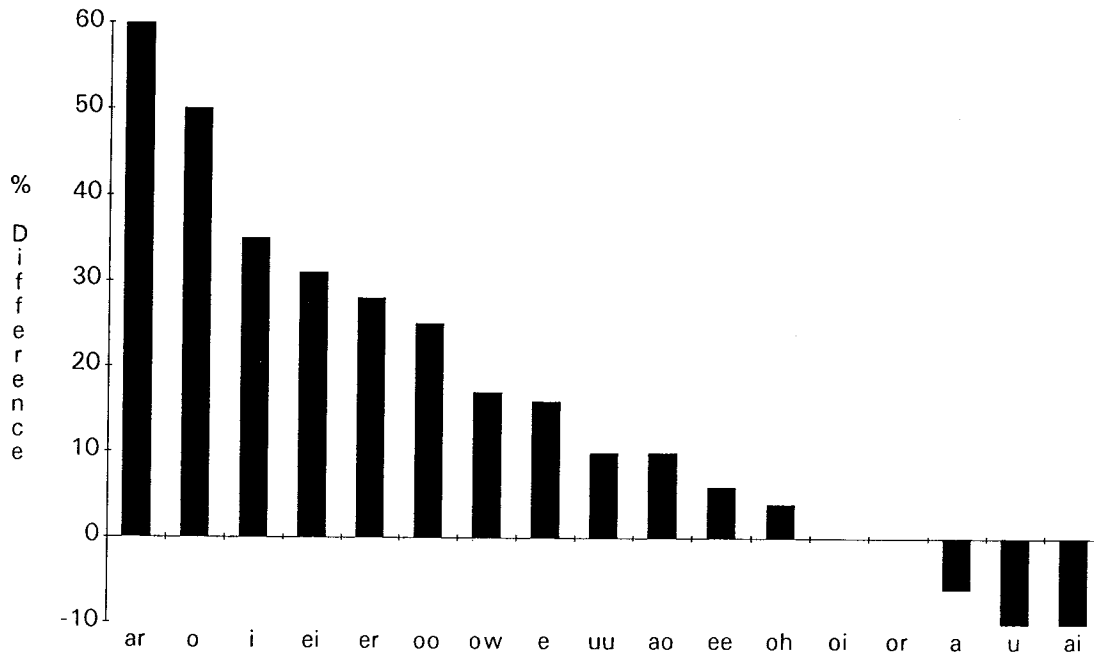


Subject 4

Medial Vowels

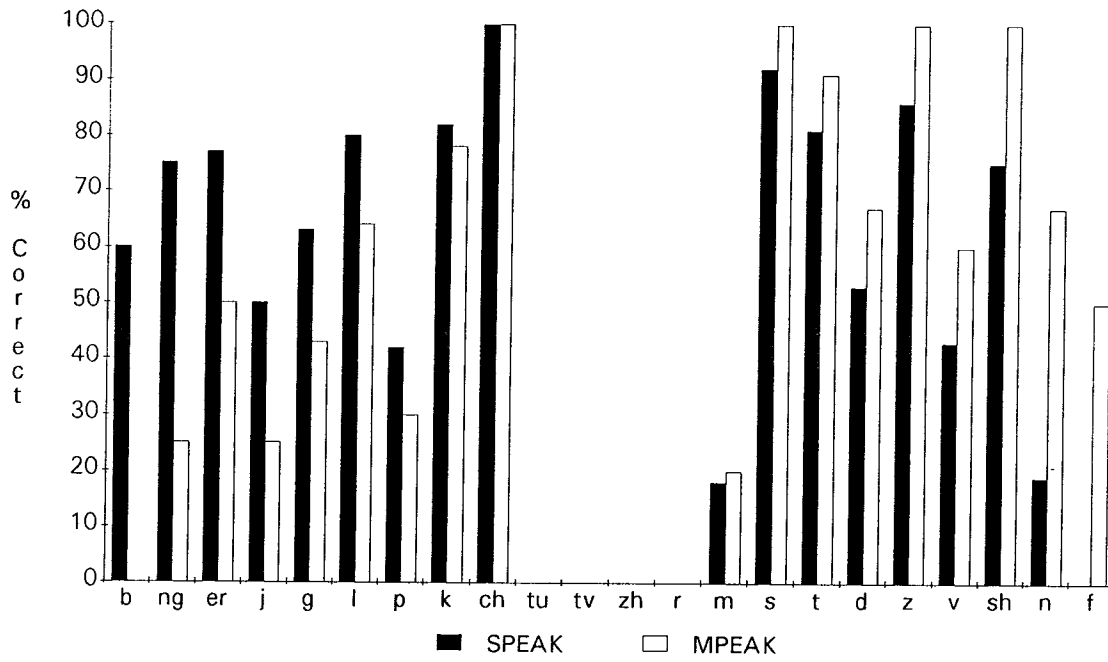


Medial Vowels

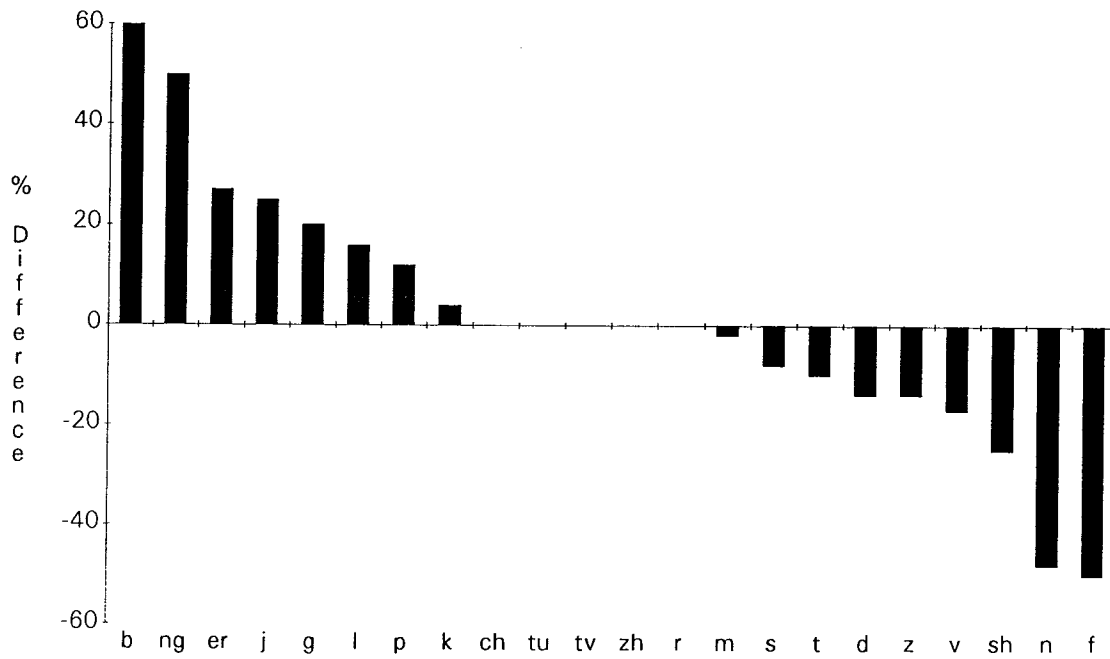


Subject 4

Final Consonants



Final Consonants



MPEAK- % Scores- Subject 5

Initial Consonants

	RESPONSE																																											
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R																				
P	23		31		31		8									8									7																			
B		36		21		14		7								7				14					7																			
T			91		9																				6																			
D				83		17																			6																			
K	14				43								14												7																			
G		13				63																			4																			
F		13					13	38			25			13											4																			
V									33																2																			
TU								50		50															1																			
TV											0														1																			
S												100													7																			
Z																									NP																			
SH																									4																			
CH			25																						4																			
J			33	17											50										3																			
H			8												8	75	8								6																			
M																	25	17							6																			
N				11														11	56						5																			
W						10																			5																			
WH																									2																			
Y																									2																			
L		7			7	7																			8																			
R																									8																			
																								3	4	12	9	7	7	3	1	1	10	1	5	2	7	3	6	5	2	8	9	57.0%

Vowels

		RESPONSE																																								
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO																							
Eve	EE	88	6		6																				8																	
It	I	5	86	5									5												11																	
Met	E		7	67	7							13													8																	
Have	A			10	62					5				10		10	5								11																	
Heart	AR					0																			2																	
Dog	O						100																		1																	
Corn	OR					17						33													3																	
Foot	OO											75													2																	
Boot	UU											10	70												5																	
Up	U											6	69	6											8																	
Bird	ER			17	8								8	42											6																	
Say	EI	11	6		11							6													9																	
Go	OH				7							7													7																	
I	AI				13	6																			8																	
Out	OW				25																				4																	
Boy	OI																								2																	
More	AO					7																			7																	
																								9	12	9	11			1	1	3	5	8	3	9	9	8	5	2	8	67.5%

Final Consonants

		RESPONSE																																													
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M		N	NG	L	R	ER																							
P		55		27	9	9																			6																						
B			17		33					17															3																						
T				77		5			5							5									11																						
D			6		56		6			6				6								6	13		8																						
K		12		24		53					6														9																						
G		14		29	29		14																		4																						
F				14		14			29					14											4																						
V										50															4																						
TU																									3																						
TV											33														3																						
S												0													1																						
Z													75		17										6																						
SH													33	67											3																						
CH		25				25		25																	2																						
J																									NP																						
H																									3																						
M																									2																						
N																									5																						
NG																									11																						
L																									2																						
R																									11																						
ER																									1																						
																								6	2	17	10	8	1	2	4	2		7	4	2		2	2	4	8	4	10		8	2	54.0%

SPEAK- % Scores- Subject 5

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	
P	38			8	31	8								8	8										7
B		85		15																					7
T			92		8																				6
D				83						8												8			6
K					62																				7
G						56																			5
F		11					60						10										11		5
V		10	10										10												5
TU		50						0					25									25			2
TV	33								33																2
S	50	50								0															1
Z											100														7
SH												0													1
CH													71												4
J														100											2
H															14	86									4
M																	25								6
N					50													18	9				8		6
W					9														90						6
WH																									5
Y																									5
L																									1
R																									2
																									8
																									7
	5	9	9	8	10	3	4		1	2	9		3	3	4	2	2	5	7	7	3	8	7	1	66.5%

Vowels

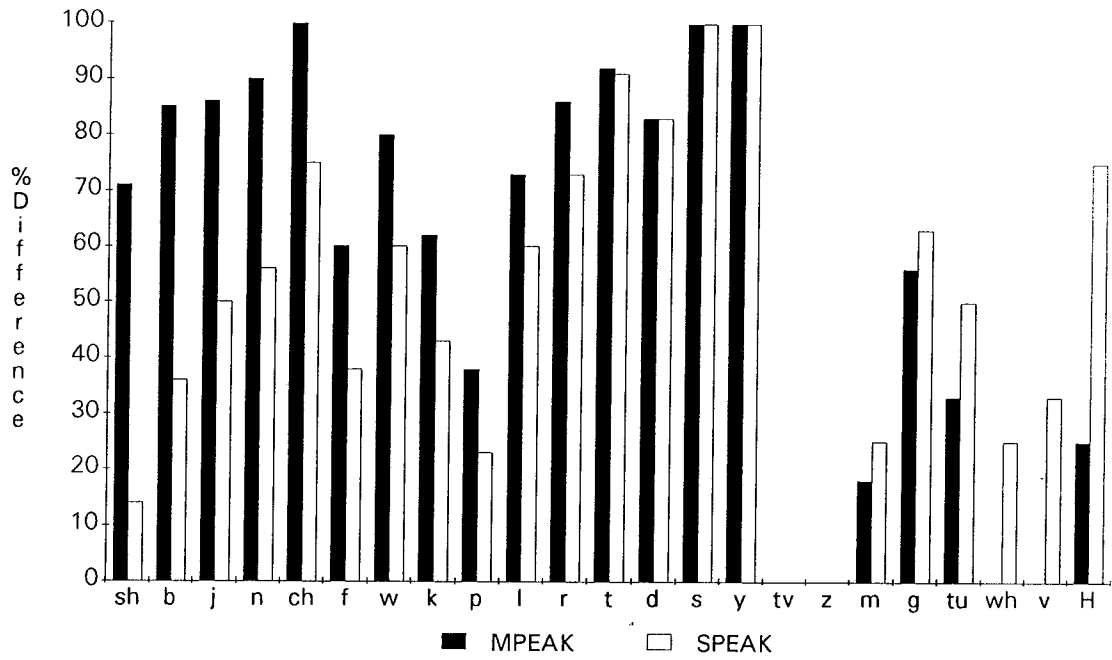
	RESPONSE																								
	EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW		OI	AO							
Eve	89		6															6							9
It	14	55	23															9							11
Met	7	7	60	7														20							8
Have	5		14	67							5											5			11
Heart					50					25															2
Dog						50																		25	2
Corn							60																	50	1
Foot								25																20	3
Boot																								25	2
Up																								8	6
Bird																								8	6
Say																								11	10
Go																								20	5
I																								89	10
Out																								5	5
Boy																								87	10
More																								15	5
																								85	7
																								25	8
																								25	7
																								100	2
																								50	1
																								80	8
																								100	1
																								80	8
	11	7	11	8	2	2	3	2	4	7	6	13	10	7	1	1	10	1	10	1	1	10	1	68.0%	

Final Consonants

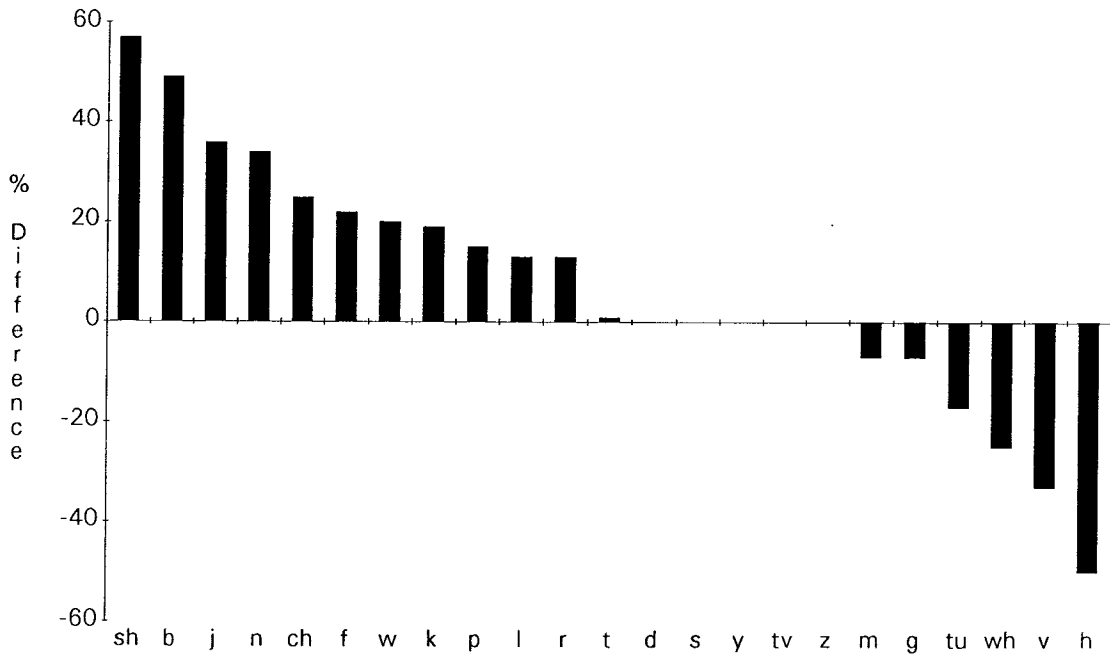
	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER		
P	73																								6
B		60																							3
T			18																						11
D				20																					7
K					14																				7
G						7																			9
F																									4
V																									3
TU																									3
TV																									3
S	20																								1
Z																									6
SH																									4
ZH																									2
CH																									1
J																									3
M																									2
N																									6
NG																									11
L																									2
R																									11
ER																									NP
																									7
																									7
																									7
	6	2	11	8	12	2	2	2	2	1	5	5	2	4	1	1	1	12	2	13	8	5	85	5	61.5%

Subject 5

Initial Consonants

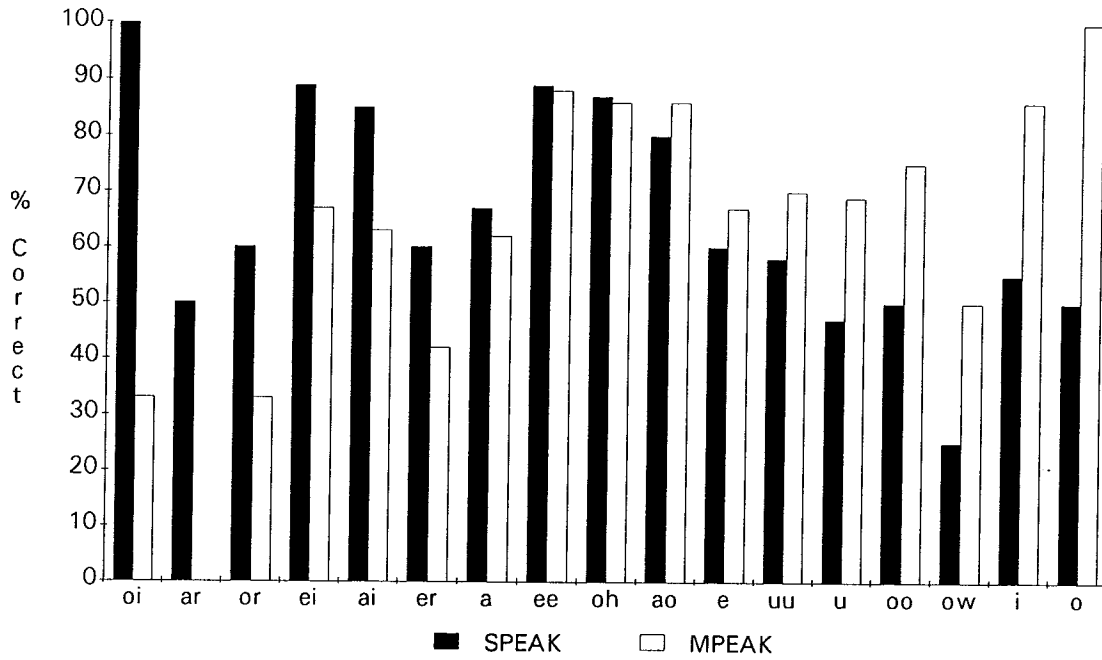


Initial Consonants

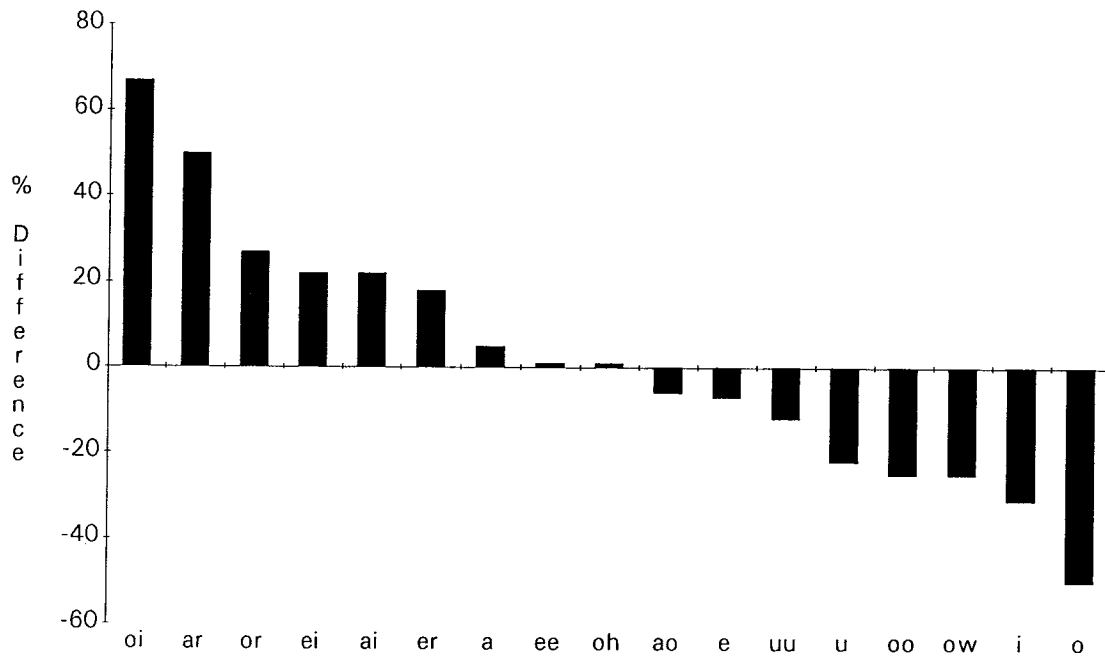


Subject 5

Medial Vowels

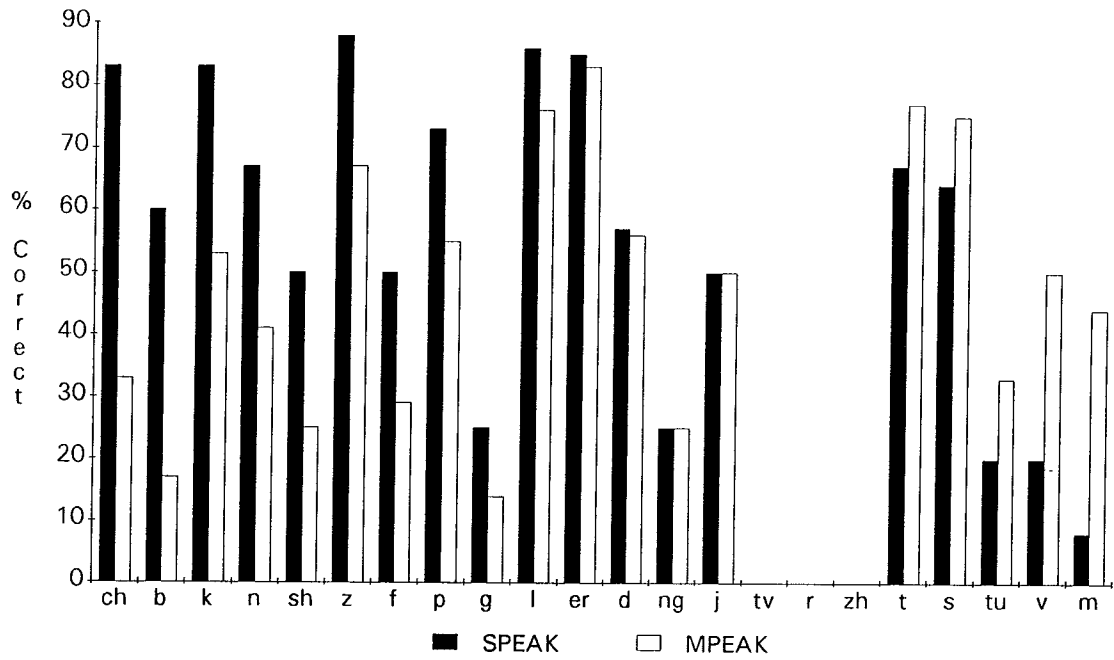


Medial Vowels

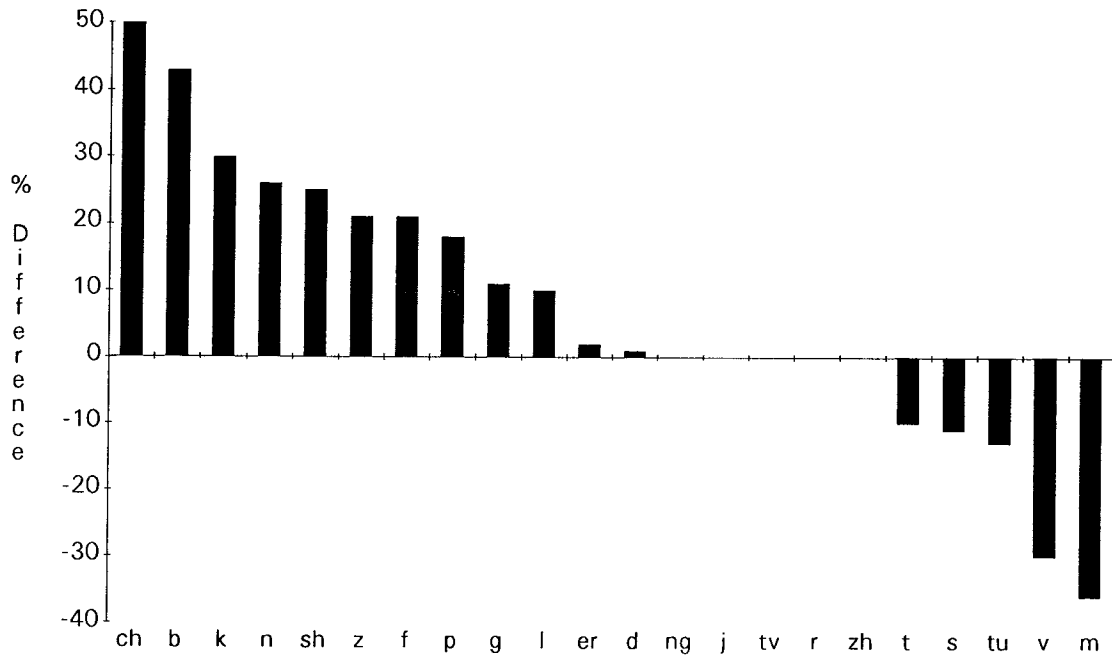


Subject 5

Final Consonants



Final Consonants



MPEAK- Raw Scores- Subject 6

Initial Consonants

		RESPONSE																									
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-		
P	5					2											1						1			14	
B		6					1					1					2	1							2	13	
T			9			1									1											11	
D			2		8																				2	12	
K				4		9									1										2	13	
G					3			4												1	1					8	
F								2	1			1														9	
V									1							1										3	
TU										1																2	
TV																										1	
S												13							1							1	
Z																										13	
SH																										0	
CH																										7	
J																6										6	
H																	7									12	
M																		6	2		1					12	
N																		3	4							8	
W																					7	1				10	
WH																					1	1				4	
Y																							3			4	
L																								3	3	1	15
R																										1	16
		5	11	23	11	16	6	4	3	0	0	20	0	2	6	7	11	16	12	16	2	4	7	11	7	52.5%	

Vowels

		RESPONSE																		
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-	
Eve	EE	16																		16
It	I	2	14	1						1	1	1			1				21	
Met	E	2		10	1			1						1				1	16	
Have	A			1	17									2					20	
S Heart	AR			1	1	1													5	
T Dog	O					1										1		1	2	
I Corn	OR			1	1					3								1	5	
M Foot	OO										4	1							5	
U Boot	UU									1	7								9	
L Up	U			2								5	1					1	16	
U Bird	ER							1	2				9		4		2	2	12	
S Say	EI		1	1										15		2			19	
Go	OH							1							9	1		2	14	
I	AI															14		1	16	
Out	OW			1									1				1		7	
Boy	OI															3		3	7	
More	AO																	4	13	
		20	15	18	20	2	1	7	8	10	6	11	18	17	17	4	10	16	0	70.0%

Final Consonants

		RESPONSE																							
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER	-	
P	6					1																			11
B			1																	1					5
T				17		2					1											1			22
D					9						2			1								2			16
K					5						1				1									2	17
G							2														1				7
F								2														1			6
V									2					1										1	5
TU										2												1			7
TV											1														1
S																									1
Z													12												12
SH																									6
ZH																						2			4
CH																									4
J																									1
M																									6
N																									4
NG																									10
L																									22
R																									4
ER																									21
		7	1	28	21	14	2	2	6	3	0	19	8	6	0	1	1	11	18	3	20	1	21	7	53.5%

MPEAK- % Scores- Subject 6

Initial Consonants

	RESPONSE																									
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-		
P	36		36		14												7					7				7
B		46				8					8					15	8								15	7
T			82		9								9													6
D		17		67																				17		6
K			31		69																					7
G				25		50													13	13						4
F			33	11			22	11			11					11										5
V								33							33											2
TU					50		50		0																	1
TV										0							100									1
S											100															7
Z																										NP
SH																										4
CH			14		14																					4
J														100												3
H		8	8					8							58									17		6
M																		50	17	8			17	8		6
N																		38	50				13			4
W		20																		70	10					5
WH					25		25													25	25					2
Y						7	25															75				2
L																							20	20	7	8
R																							6	44		8
	3	6	12	6	8	3	2	2			10		1	3	4	6	8	6	8		2	4	6	4	52.5%	

Vowels

	RESPONSE																									
	EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW	OI		AO								
Eve	EE	100																								8
It	I	10	67	5				5	5	5			5													11
Met	E	13		63	6			6				6	5										6			8
Have	A			5	85							10														10
S Heart	AR			20	20	20									20										20	3
T Dog	O					50	0																	50		1
I Corn	OR			20	20			60																		3
M Foot	OO								80	20																3
U Boot	UU								11	78																5
L Up	U			13							31	6											13	13		8
U Bird	ER							8	17			75														6
S Say	EI		5	5									79													10
Go	OH							7						64	7							7	14			7
I	AI										6				88							6				8
Out	OW			14												43										4
Boy	OI																							100		2
More	AO							8	8		8												8	69		7
		10	8	9	10	1	1	4	4	5	3	6	9	9	9	2	5	8								70.0%

Final Consonants

	RESPONSE																									
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER	-		
P	55		36		9																					6
B		20		40													20				20					3
T			77	5	9				5															5		11
D				56				13					6									13				8
K			29	6	41			6		6		6														9
G				29	14	29																				4
F			17		17		33				17										14		14			4
V								40																17		3
TU	14			29	14				14		29														20	3
TV										100		0														4
S											100															1
Z													67													6
SH														100									33			3
ZH															0											2
CH			17	17							17				17											1
J																25					17					3
M																		50	20							2
N				14														23	36		5	5	14	5		11
NG																			50	50						2
L					5																	62		29	5	11
R																							0	100		1
ER																								83		6
	4	1	14	11	7	1	1	3	2		10	4	3		1	1	6	9	2	10	1	11	4		53.5%	

SPEAK- Raw Scores- Subject 6

Initial Consonants

		RESPONSE																									
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-		
S T I M U L U S	P	3	2	2		1		1									3									12	
	B	1	8					4																			13
	T			11	1																						12
	D				7			1	1	1			1													1	12
	K					2		11																			13
	G							8																1			9
	F								3									3									9
	V									3																	4
	TU										1																2
	TV											1						1									2
	S												11		2	1											14
	Z																										0
	SH														6	1											8
	CH															6											6
	J																8										8
	H																	1									12
	M																		5								11
	N																			7		2				2	10
	W																					7	1			1	10
	WH																					1				1	3
Y																									1	1	
L																									9	15	
R																									6	14	
		7	20	16	9	15	10	16	1	2	2	13	0	9	8	8	8	7	7	13	2	2	17	7	1	59.0%	

Vowels

		RESPONSE																		
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-	
S T I M U L U S	Eve	EE	12	3										2						17
	It	I	2	14	1									5	1					23
	Met	E	1	4	6							1	2							14
	Have	A			4	15								3						22
	Heart	AR					3													5
	Dog	O															1		1	2
	Corn	OR								1									2	4
	Foot	OO									2								3	2
	Boot	UU										2								13
	Up	U									9				1				1	18
	Bird	ER										1			3				4	11
	Say	EI											1	6					1	18
	Go	OH													16				1	16
	I	AI														11			3	14
	Out	OW														2		12		5
	Boy	OI																	4	2
More	AO																	2	14	
		16	23	12	15	4	0	2	6	9	10	7	30	18	13	5	3	27	0	67.0%

Final Consonants

		RESPONSE																								
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER	-		
S T I M U L U S	P	4			3	1	4																			12
	B		1						1	1										2						5
	T			16			5																			22
	D				1	8	1				2				1											15
	K					3	1	11						1											2	17
	G						1	2	2													1				8
	F								1																1	6
	V									3																7
	TU										1															4
	TV											1														1
	S												5	1	3										1	12
	Z													1	4											8
	SH															2										4
	ZH																1									0
	CH																	5								6
	J										1								2							4
	M																			2						11
	N																				1		4		1	21
	NG																				10	1	2		2	4
	L																					1			3	20
R																						16		2	0	
ER																								6	13	
		6	3	34	15	26	3	4	8	1	1	8	9	5	0	6	4	4	4	13	2	28	1	11	8	49.5%

SPEAK- % Scores- Subject 6

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	
P	25	17	17		8											25									6
B	8	62																							7
T			92		8																				6
D				58		8	8	8																	6
K					85																				7
G						89																			5
F		22	11																						5
V																									2
TU																									1
TV																									1
S																									7
Z																									7
SH																									NP
CH																									4
J																									3
H																									4
M																									6
N																									6
W																									5
WH																									5
Y																									2
L																									1
R																									8
																									7
	4	10	8	5	8	5	8	1	1	1	7	5	4	4	4	4	4	4	7	7	1	9	4	1	59.0%

Vowels

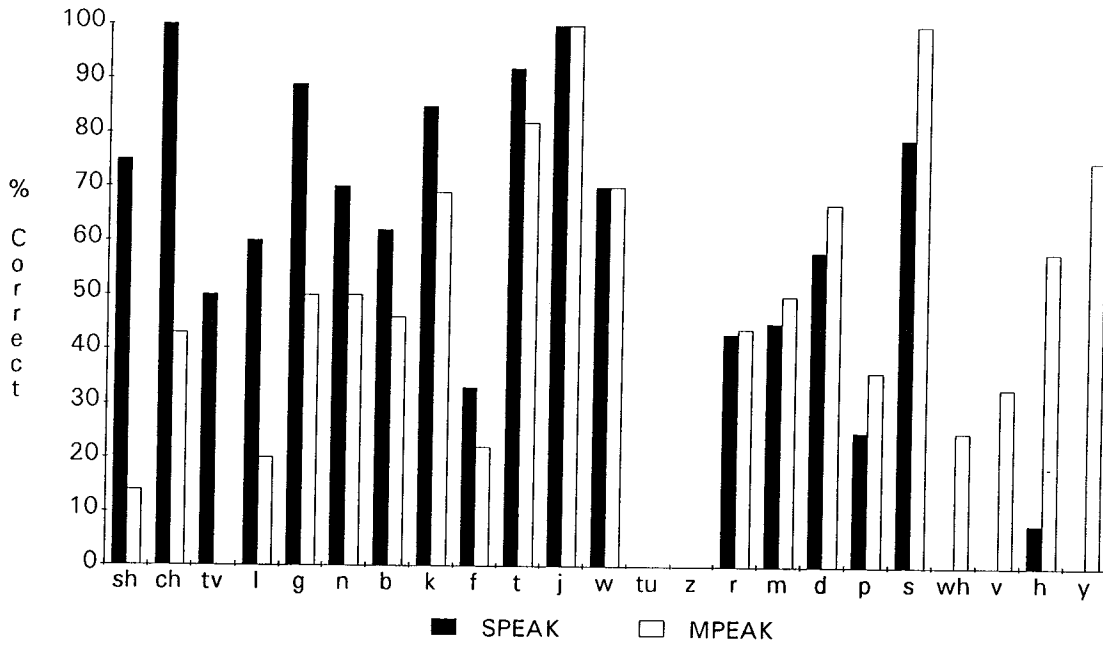
	RESPONSE																									
	EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW	OI		AO								
Eve	EE	71	18																							9
It	I	9	61	4																						12
Met	E	7	29	43																						7
Have	A			18	68																					11
Heart	AR				60																					3
Dog	O					0																				1
Corn	OR						25																			2
Foot	OO							100																		1
Boot	UU								15	69																7
Up	U								6		50															9
Bird	ER			9																						6
Say	EI	6	6																							9
Go	OH								6																	8
I	AI																									7
Out	OW				20																					3
Boy	OI																									1
More	AO																									7
		8	12	6	8	2		1	3	5	5	4	15	9	7	3	2	14								67.0%

Final Consonants

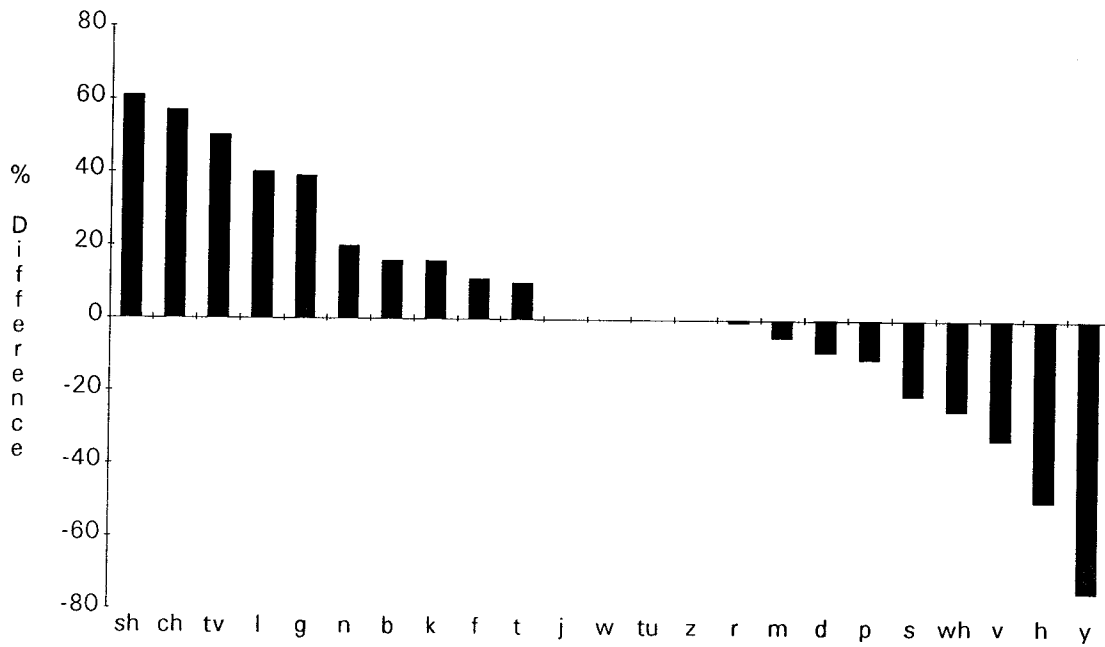
	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER		
P	33		25	8	33																				6
B		20																							3
T			73		23																				11
D				7	53																				8
K					6	65																			9
G																									4
F		13			13	25	25																		3
V																									4
TU																									4
TV																									2
S																									1
Z																									6
SH																									4
ZH																									2
CH																									NP
J																									3
M																									2
N																									6
NG																									11
L																									2
R																									10
ER																									NP
																									7
	3	2	17	8	13	2	2	4	1	1	4	5	3	3	2	2	7	1	14	14	1	6	4	49.5%	

Subject 6

Initial Consonants

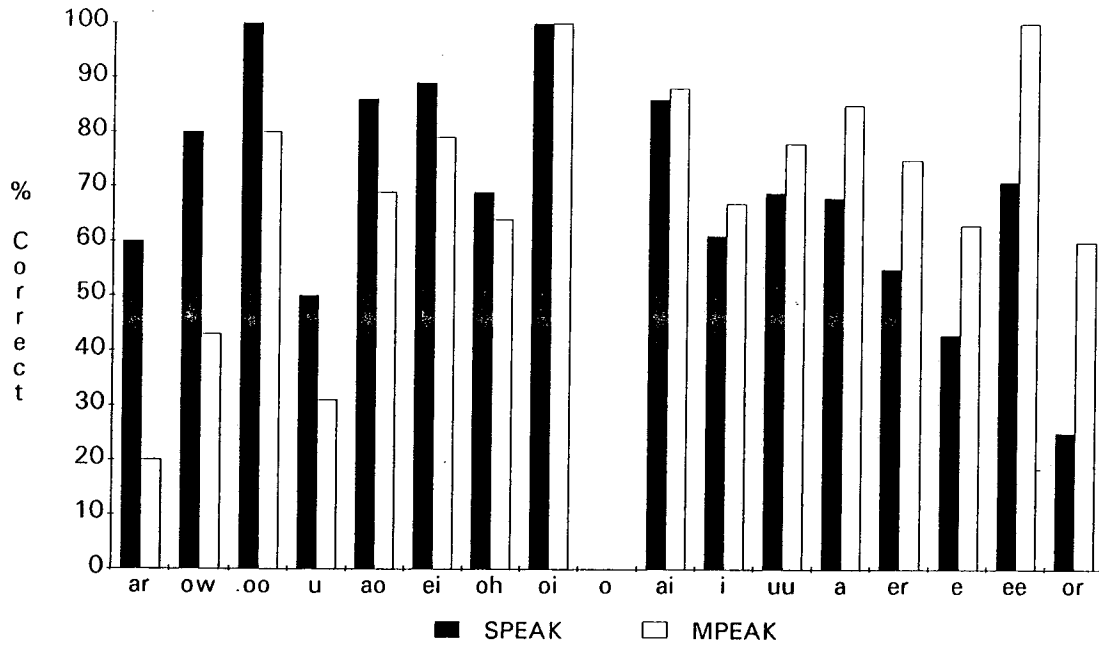


Initial Consonants

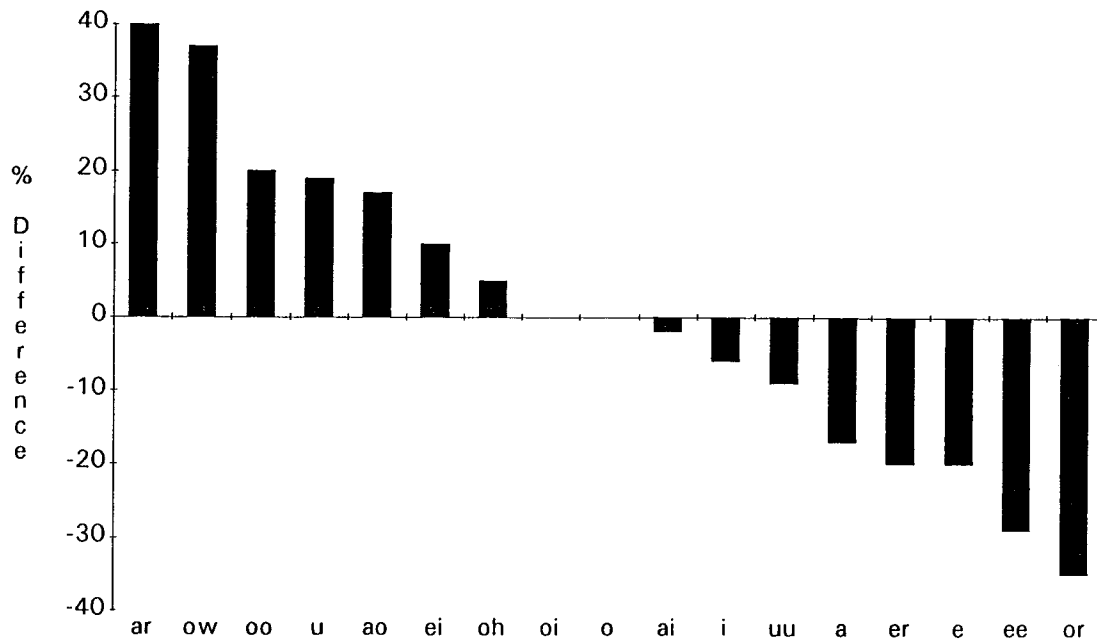


Subject 6

Medial Vowels

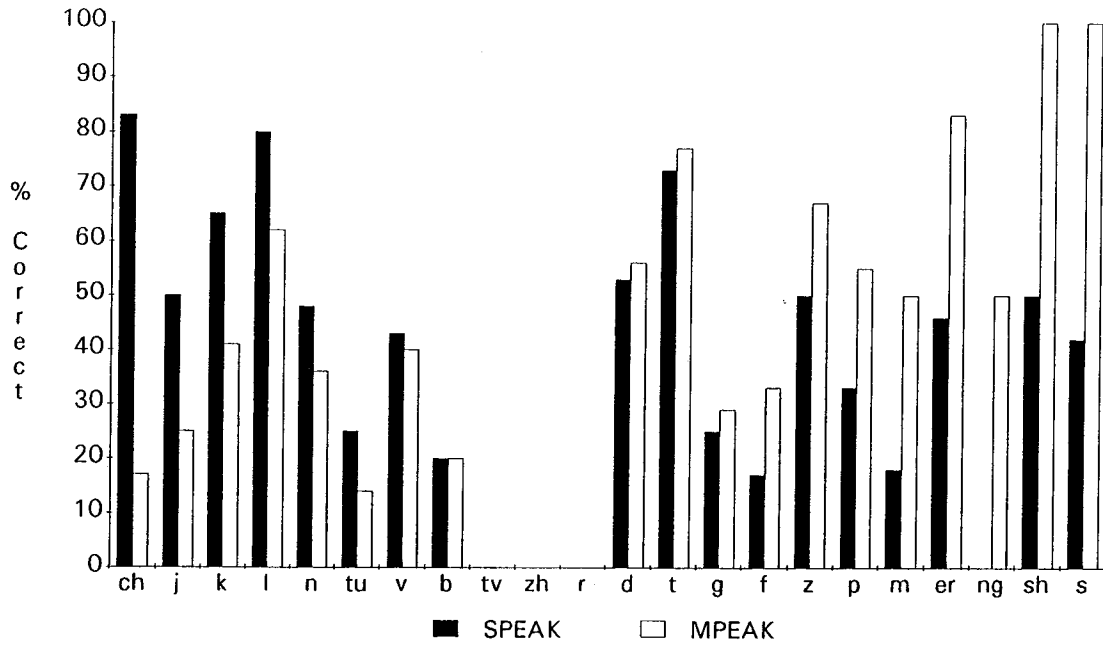


Medial Vowels

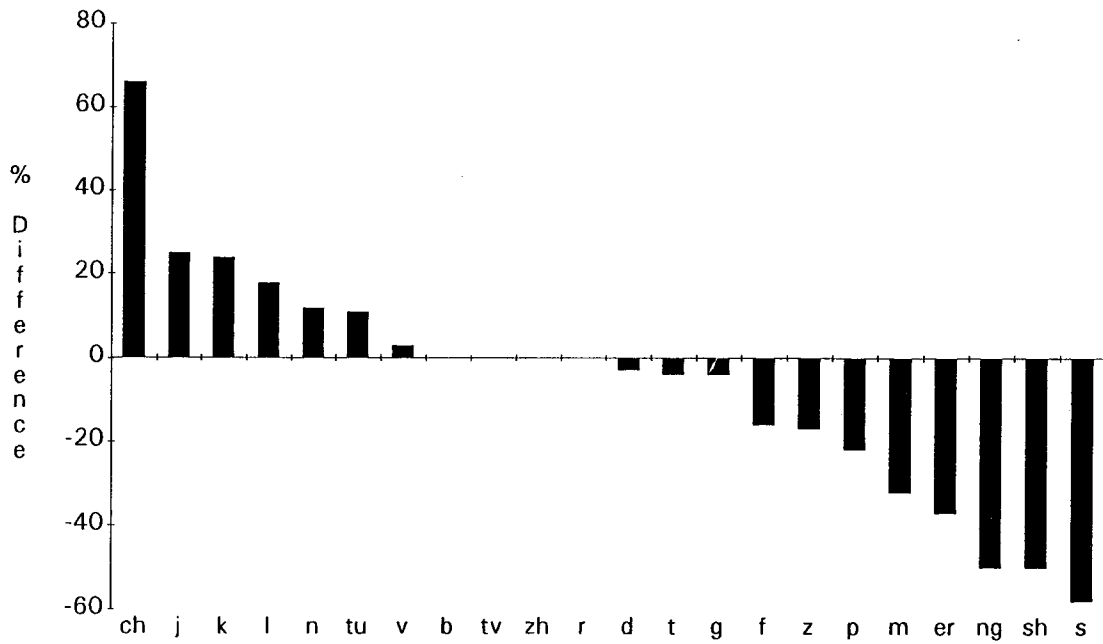


Subject 6

Final Consonants



Final Consonants



MPEAK- Raw Scores- Subject 7

Initial Consonants

		RESPONSE																									
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R			
S T I M U L U S	P	12				1												1								14	
	B		12															1	1								14
	T			11																							11
	D				11																						12
	K	1		2		10									1												14
	G		2				4														1						8
	F	3	1		1			4											1								9
	V		1						1												1						3
	TU	1																									1
	TV																										1
	S											8			3	2											13
	Z														7												0
	SH															7											7
	CH																7										7
	J																6								1		7
H																	11									12	
M																		8							1	12	
N																			1		1					9	
W																					6				4	10	
WH					1																1	1			1	4	
Y																							3			3	
L																								4	5	14	
R																			2	1	1	1			15	15	
		17	17	13	12	12	4	4	1	0	0	8	0	11	9	6	13	14	14	9	2	4	4	26	0	74.5%	

Vowels

		RESPONSE																								
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO								
S T I M U L U S	Eve	EE	12																	4					16	
	It	I		12	5	1				1	1	1								1					22	
	Met	E	1		13	1															1				16	
	Have	A				17															1				21	
	Heart	AR					3																		3	
	Dog	O						2																	2	
	Corn	OR					1	1	2															1	5	
	Foot	OO								3											1				1	4
	Boot	UU									6										3					10
	Up	U										13													2	16
	Bird	ER											12													12
	Say	EI												18												18
	Go	OH									1	1			12											14
	I	AI															16									16
	Out	OW																6								7
Boy	OI																							3	3	
More	AO							2	1															12	15	
		13	12	20	19	4	5	3	4	8	15	12	26	18	17	6	3	15	0						80.0%	

Final Consonants

		RESPONSE																									
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER				
S T I M U L U S	P	6				2		2																		11	
	B		5																	1						6	
	T			22																						22	
	D				9				1		1											3		1		1	16
	K					17																					17
	G						4																				7
	F	1			3			4																			6
	V						1		4																		5
	TU				2					1																	6
	TV					2																					1
	S												11														11
	Z																										7
	SH																										4
	ZH																										1
	CH																	6									6
J																		4								4	
M																			3						1	9	
N																					14		2		4	3	23
NG																					3		1				4
L																							19			2	21
R																										1	1
ER																										11	12
		7	5	26	16	19	7	7	2	0	0	11	8	4	0	6	4	4	25	1	25	0	16	7		74.0%	

SPEAK- Raw Scores- Subject 7

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	
P	9				1		1									1									12
B		9						1												2				1	13
T			9	1	2																				12
D		3		8			1																		12
K	3		1		9																				13
G				2		5																1	1		9
F		1					4			2						2									9
V								1									2								4
TU									2															1	3
TV	1			1												1									3
S											12		2												14
Z					1																				1
SH													7												7
CH			1											4											5
J			1												6										7
H	3				1		1									7									12
M																	2	3	1					5	11
N																		7						3	10
W																			4						9
WH		1																	1						2
Y				1																		1			2
L		2			1												1	1	2				4	5	16
R																		2						12	14
	16	16	12	14	14	5	9	2	0	0	14	0	9	4	6	11	5	13	10	0	2	4	34	0	60.0%

Vowels

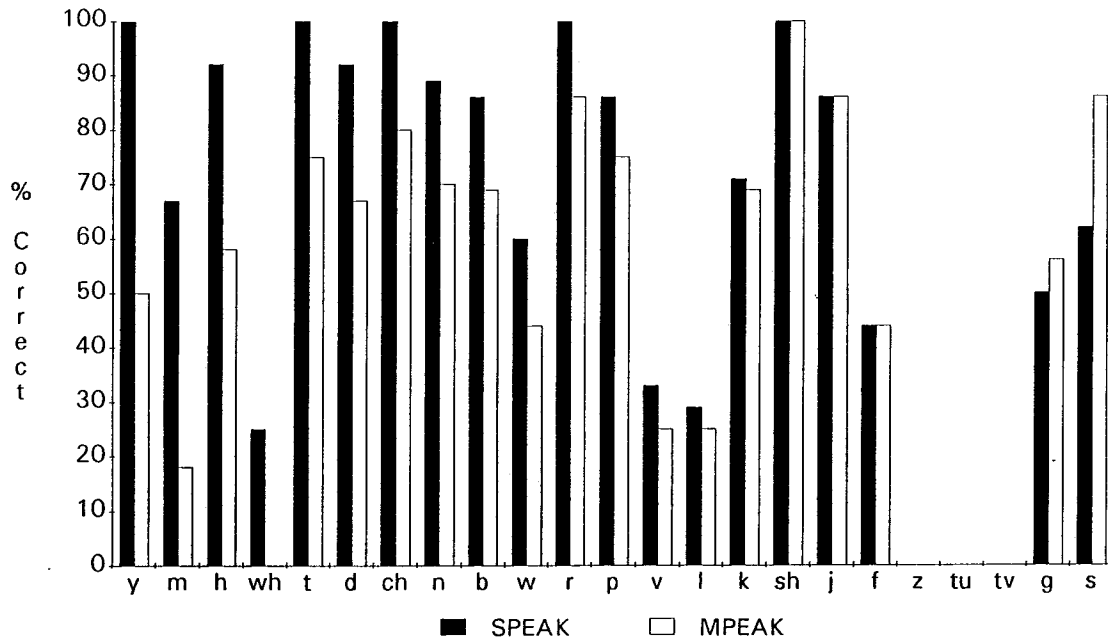
		RESPONSE																							
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI		AO						
Eve	EE	18																							18
It	I	1	15	5					1																22
Met	E		1	14																					15
Have	A			3	17														1						21
S Heart	AR					1	1	1											1			1			5
T Dog	O						1																	1	2
I Corn	OR				1				2						1										4
M Foot	OO							1	2																3
U Boot	UU															13									13
L Up	U			2											16	1									19
U Bird	ER			3						1	1						5								10
S Say	EI				1													17			1				19
Go	OH			1																13				1	15
I	AI			1	1																	10	1		13
Out	OW																			1			3		4
Boy	OI																							2	2
More	AO							1	1						3					1	1			8	15
		19	16	29	20	1	2	5	5	14	20	6	18	16	12	5	2	10	0	78.0%					

Final Consonants

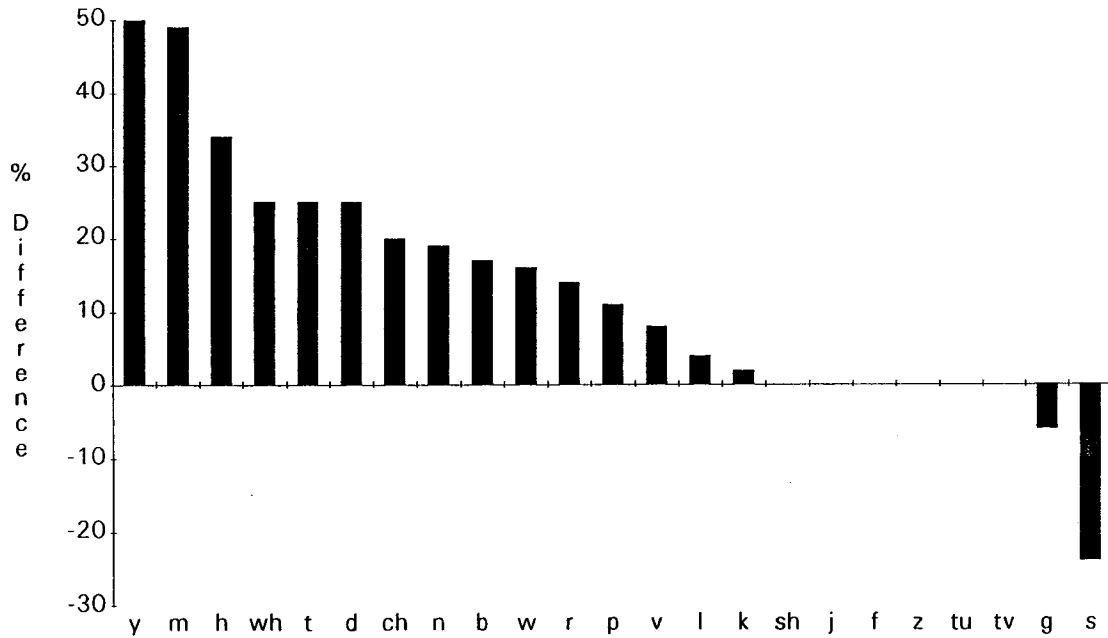
		RESPONSE																							
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER	
P		4	1	3		2																		1	11
B			1															1	2		1				5
T		2		17		3																			22
D			1	8		3														1			1		14
K			3		15																				18
G				1		7																			8
F			1				4				1														6
V								2													1	1		2	6
TU			1						2														1		4
TV																								1	2
S																									4
Z							1				9		1		1										11
SH													7			1									8
ZH														4											4
CH															1										0
J																	6								7
M																		3							4
N				1															3	4		2	1	1	12
NG				1															2	12		1	2	2	20
L				1																1	2				4
R																						20			21
ER																									0
		6	2	26	12	20	10	5	2	2	0	10	8	6	1	6	3	6	22	2	28	0	17	6	68.5%

Subject 7

Initial Consonants

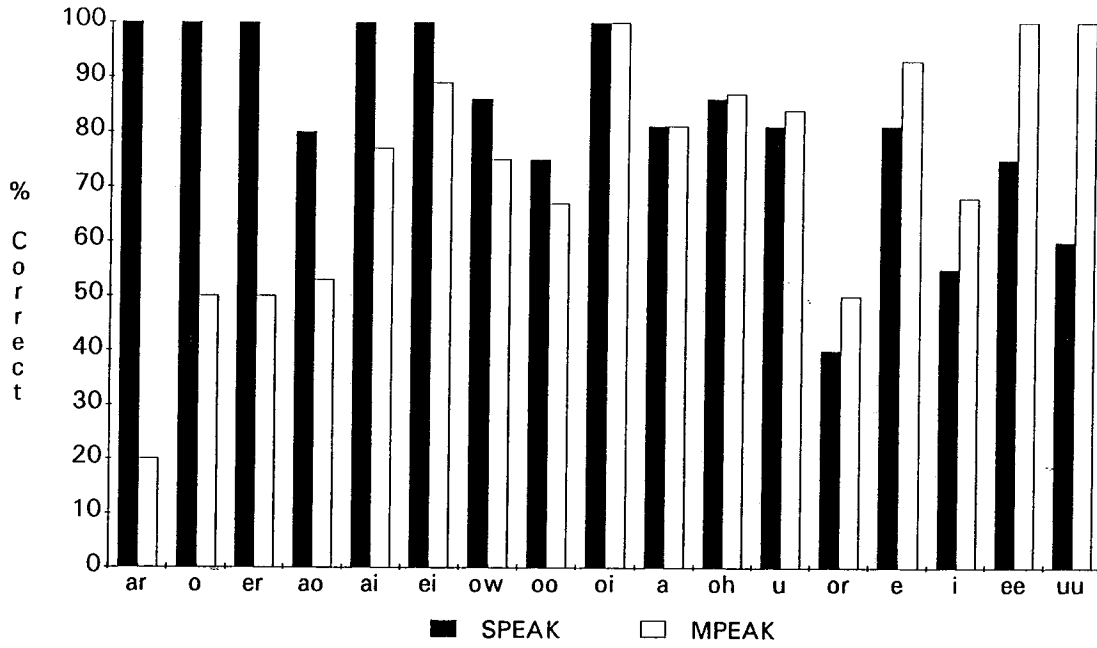


Initial Consonants

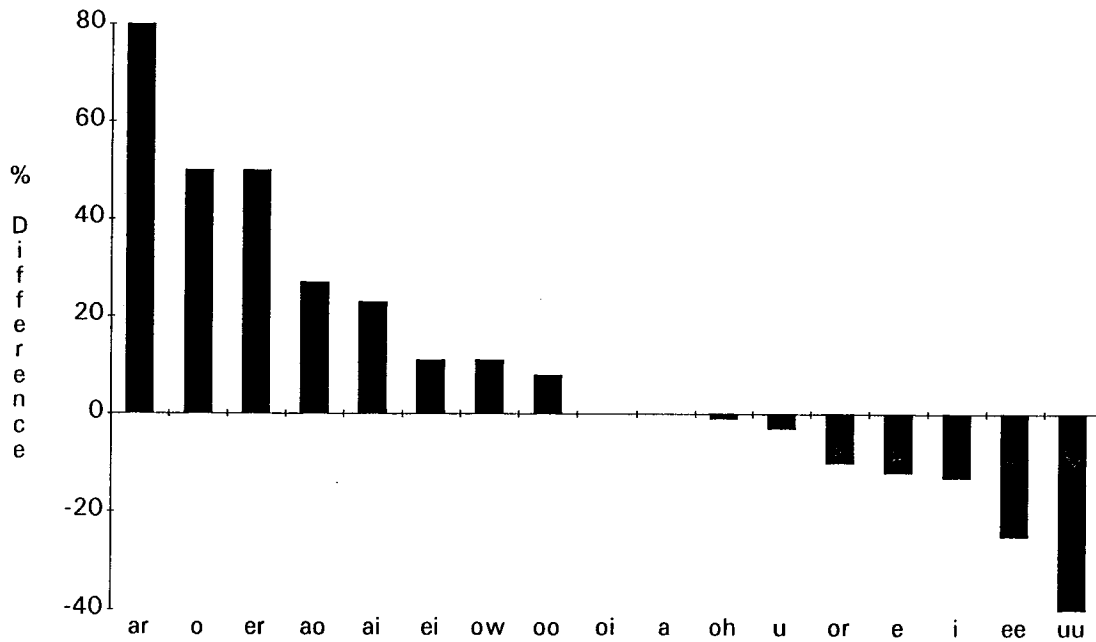


Subject 7

Medial Vowels

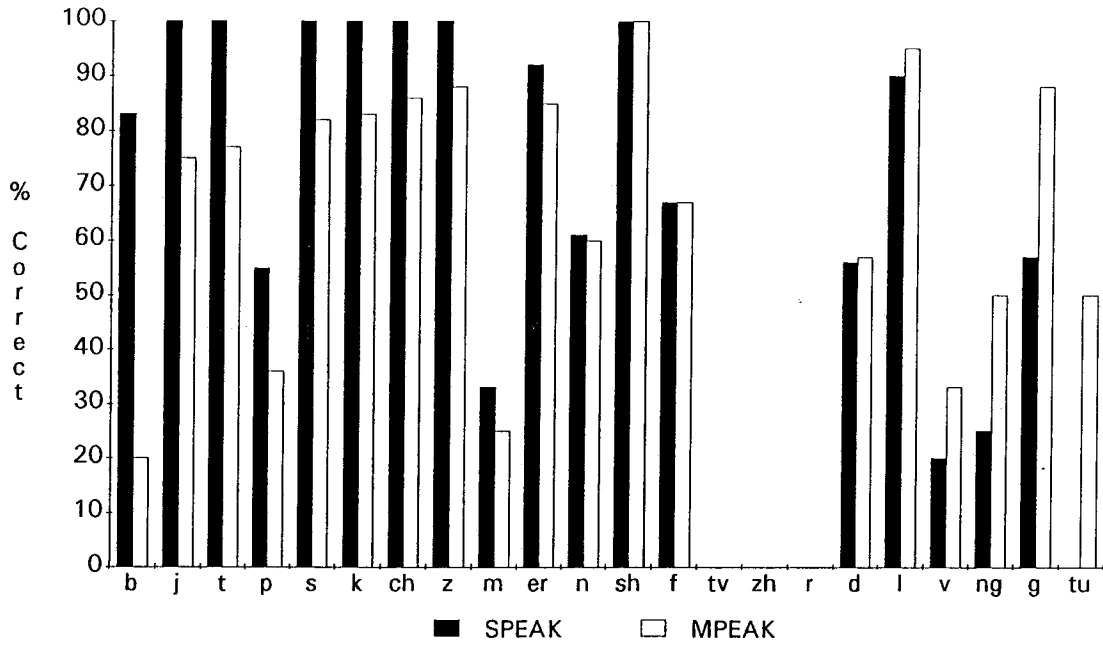


Medial Vowels

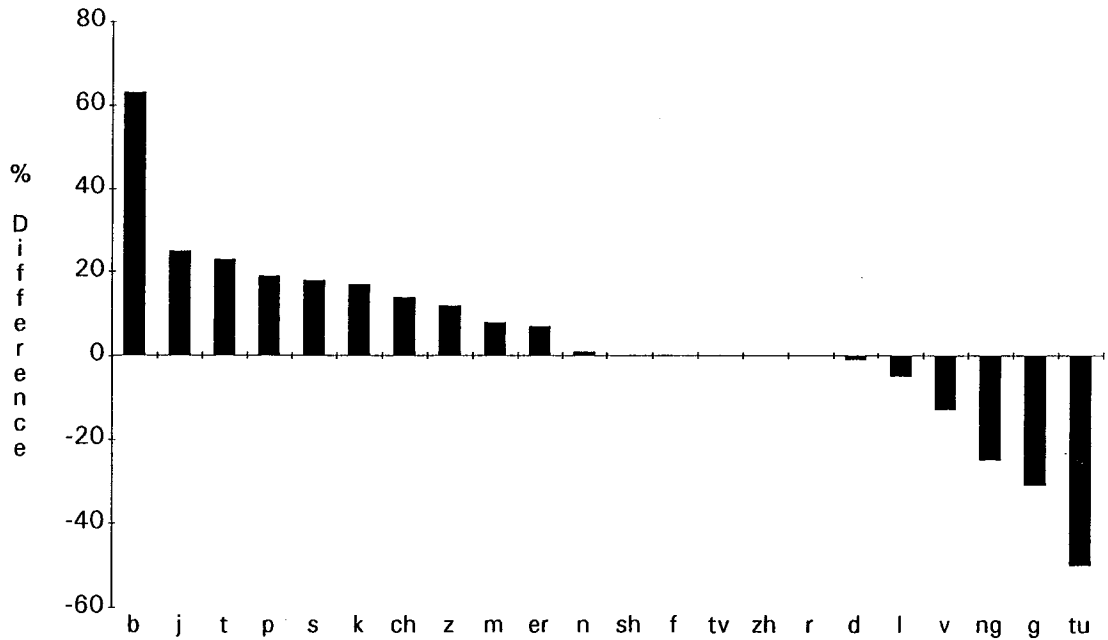


Subject 7

Final Consonants



Final Consonants



MPEAK- Raw Scores- Subject 8

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W		WH	Y	L	R	
P	9		2		1											1									13
B	1	7				1	1																1	2	13
T			9	1	1																				11
D			1	9		2																			12
K	1		4	1	7										1										14
G				2		6																			8
F							6			1														1	8
V		1						1											1						3
TU	1	1					1																		3
TV		1		1																					2
S										12		1	1												14
Z				1																					1
SH												5	1												6
CH												1	6												7
J														6											6
H	1					1									10										12
M																4	1	3				2	1		12
N		1															7						1		9
W		1																5					3		9
WH		2																	5				1		3
Y				1																		2			3
L		3																					11	2	16
R																3		1					3	8	15
	13	18	16	16	9	9	9	1	0	0	13	0	7	8	6	12	7	8	10	0	2	17	16	3	65.0%

Vowels

		RESPONSE																							
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO						
Eve	EE	16																			1				17
It	I		17	3					1																21
Met	E			11	1									2				1							15
Have	A		1	1	17												1								20
Heart	AR					3																		2	5
Dog	O																							1	1
Corn	OR				1				2			1												1	5
Foot	OO									5															5
Boot	UU										9				2										11
Up	U							2				12			3										17
Bird	ER												9		1									1	11
Say	EI	1		1							1					16									19
Go	OH		1								3		2				8								14
I	AI				2							1						10	2						15
Out	OW																	1		5					6
Boy	OI														1							2			3
More	AO				2							3					1	1					8		15
		17	19	16	23	3	0	2	8	13	18	11	19	16	12	8	2	13	0						75.0%

Final Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG		L	R	ER		
P	2		2	1	4																			1	10
B		3		1																2					6
T			21		1																				22
D				14		1																			15
K			7		8	1			1													1			18
G				2	2	3																			7
F							6																		6
V				1			1	2											1					1	6
TU	1			1	1					3															6
TV											1														1
S												9	1												12
Z			1		1								6												6
SH														4											4
ZH																									0
CH															7										7
J																4									4
M					1				1								3	6							11
N				2					1								2	11	1					4	21
NG				1															3						4
L																			1		17		2	2	22
R																									0
ER				1		1																3	6	1	12
	3	3	31	25	17	6	7	4	4	1	9	7	4	0	7	4	5	21	4	21	0	8	9	66.5%	

MPEAK- % Scores- Subject 8

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	
P	69		15		8											8									7
B	8	54				8	8															8		15	7
T			82	9	9																				6
D			8	75		17																			6
K	7		29	7	50										7										7
G				25		75																			4
F						75					13													13	4
V		33					33												33						2
TU	33	33					33		0																2
TV		50		50					0																1
S										86		7	7												7
Z				100							0														1
SH												83	17												3
CH												14	86												4
J														100											3
H	8					8									83										6
M		8														33	8	25				17	8		6
N		11															78						11		5
W		11																56					33		5
WH		67																	0				33		2
Y				33																		67			2
L																							69	13	8
R		19																					20	53	8
	7	9	8	8	5	5	5	1			7		4	4	3	6	4	4	5		1	9	8	2	65.0%

Vowels

		RESPONSE																							
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO						
Eve	EE	94																				6			9
It	I		81	14					5																11
Met	E			73	7																13			7	8
Have	A		5	5	85																				10
Heart	AR					60																			3
Dog	O						0																	100	1
Corn	OR				20			40																20	3
Foot	OO								100																3
Boot	UU									82															6
Up	U										71											18			9
Bird	ER																							9	6
Say	EI	5		5						5												84			10
Go	OH		7							21															7
I	AI				13						7														8
Out	OW																						67	13	8
Boy	OI																							83	3
More	AO				13																			67	2
		9	10	8	12	2		1	4	7	9	6	10	8	6	4	1	7							75.0%

Final Consonants

		RESPONSE																										
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N		NG	L	R	ER				
P		20		20	10	40																			10	5		
B			50		17																					3		
T				95		5																				11		
D					93		7																			8		
K				39		44	6				6														6	9		
G					29	29	43																		6	4		
F								100																		3		
V					17			17	33																	3		
TU	17			17	17					50																3		
TV											100															1		
S				8		8						75	8													6		
Z													100													3		
SH														100												2		
ZH															100											NP		
CH																100										4		
J																	100									2		
M					9				9									27	55						6			
N					10				5									10	52	5					19	11		
NG					25															75					2			
L																						5		77	9	11		
R																									9	NP		
ER				8		8																			25	50	8	6
		2	2	16	13	9	3	4	2	2	1	5	4	2	4	2	3	11	2	11					4	5	66.5%	

SPEAK- Raw Scores- Subject 8

Initial Consonants

		RESPONSE																								
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-	
P	5			1		3	1									1	1									12
B		14																								14
T				12																						12
D			2			9		1																		12
K							13																			13
G						2		7																		9
F			1						7									1								9
V			3							1																4
TU											2															2
TV			1			1																				2
S												11			1	1										2
Z																										13
SH															8											0
CH																6										8
J																	7									6
H																		7								7
M																		10	1							12
N																		1	8	1	1					11
W																			1							10
WH										1																10
Y																										3
L																										2
R																										15
																										14
																										73.0%
		5	26	13	12	16	9	9	2	0	0	11	0	9	7	8	13	11	5	16	0	3	12	13	0	

Vowels

		RESPONSE																		
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO	-	
Eve	EE	17																		17
It	I	2	19							1	1								23	
Met	E	2	1	11	1														15	
Have	A				22														22	
S Heart	AR					2										1		1	4	
T Dog	O						1											1	2	
I Corn	OR							4										1	5	
M Foot	OO								2										2	
U Boot	UU		1							11									12	
L Up	U					1			1		16								18	
U Bird	ER								1		1	6		1				2	11	
S Say	EI			1	1								16						18	
Go	OH								1	3				11					15	
I	AI				1									1		12			14	
Out	OW						1								2		3		6	
Boy	OI																	2	2	
More	AO							2		1				3				8	14	
		21	21	12	25	3	2	6	5	16	18	6	17	17	13	3	2	13	0	81.0%

Final Consonants

		RESPONSE																								
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER	-		
P	9			1		2																			12	
B			4		1																				5	
T		1		18		3																			22	
D					12	1	1		1																15	
K				3		14																			17	
G					1		7																		8	
F			2					5																	7	
V				1					4													1			6	
TU						1					1														4	
TV					1																				2	
S												10			1									1	11	
Z														1	5		1								8	
SH															4										4	
ZH																									0	
CH																	6								6	
J																		4							4	
M																			7	3					10	
N																			3	12	1	1			21	
NG																				1	3				4	
L										2												12			20	
R																								2	3	
ER					1																				1	
																							4	6	2	13
		11	4	27	17	21	8	5	7	1	0	11	5	5	1	6	4	10	17	5	18	0	9	8	71.5%	

SPEAK- % Scores- Subject 8

Initial Consonants

		RESPONSE																								
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	
S T I M U L U S	P	42				25	8									8	8								6	
	B		100																							7
	T			100																						6
	D				100																					6
	K					100																				7
	G						100																			5
	F							100																		5
	V								100																	2
	TU									100																1
	TV										100															1
	S											100														7
	Z												100													NP
	SH													100												4
	CH														100											3
	J															100										4
	H																100									6
	M																	83	8							6
	N																	9	73	9	9					6
	W																				90					5
	WH																				67	0				5
Y																						100			2	
L																						7	40	33	1	
R																						14	29	50	8	
		3	13	7	6	8	5	5	1		6	5	4	4	4	7	6	3	8		2	6	7	73.0%		

Vowels

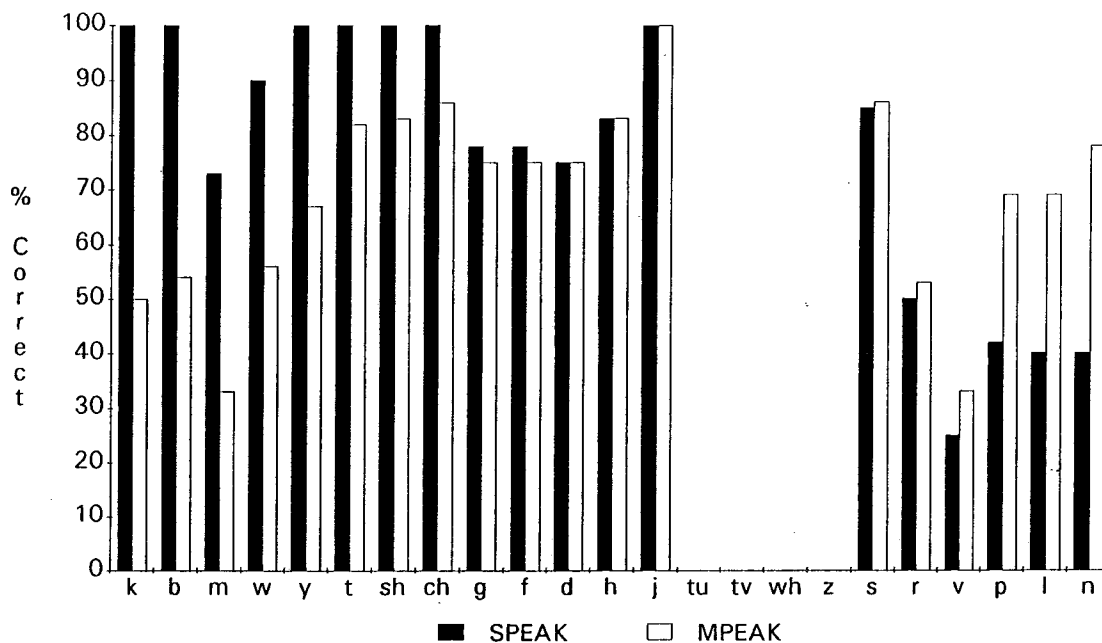
		RESPONSE																	
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI	OW		OI	AO
Eve	EE	100																	9
It	I		9	83						4	4							12	
Met	E			13	7	73	7											8	
Have	A						100											11	
S Heart	AR							50							25		25	2	
T Dog	O								50								50	1	
I Corn	OR									80							20	3	
M Foot	OO										100							1	
U Boot	UU											92						6	
L Up	U								8				6					9	
U Bird	ER									6			89					6	
S Say	EI											9	55				18	9	
Go	OH													9				8	
I	AI														73			7	
Out	OW														7	86		3	
Boy	OI																50	1	
More	AO																100	7	
		11	11	6	13	2	1	3	3	8	9	3	9	9	7	2	1	7	81.0%

Final Consonants

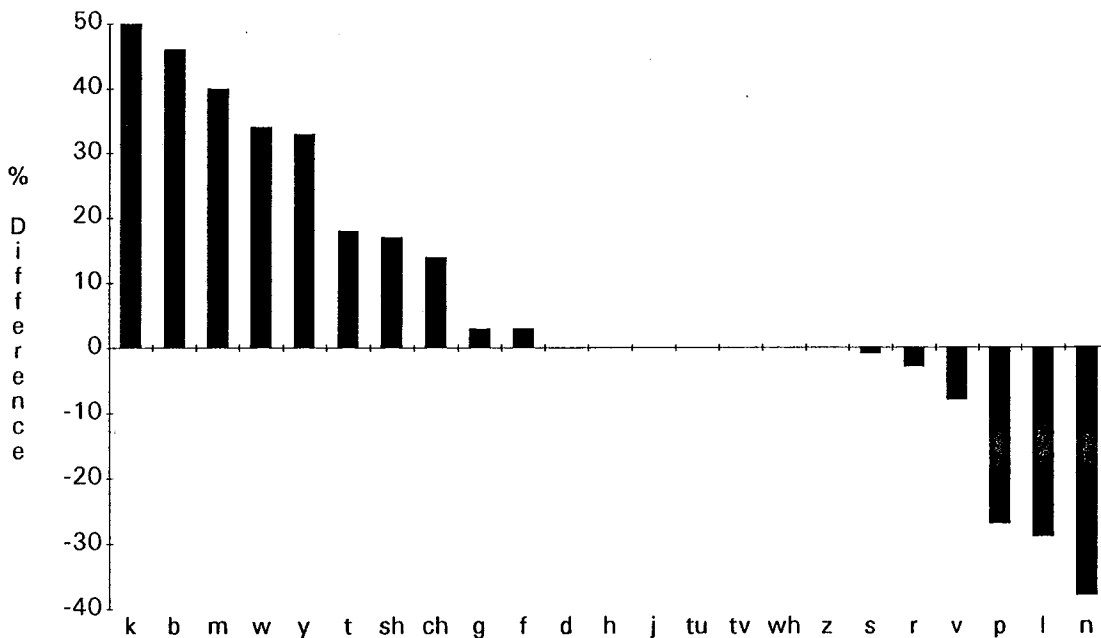
		RESPONSE																							
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER	
P	P	75																							6
B	B		80																						3
T	T			82																					11
D	D				82																				8
K	K					82																			9
G	G						88																		4
F	F							71																	4
V	V								67																3
TU	TU									25												17			2
TV	TV										0														1
S	S											91												50	6
Z	Z												13												4
SH	SH													63											2
ZH	ZH														100										NP
CH	CH															100									3
J	J																100								2
M	M																	70	30						5
N	N																	14	57	5	5			10	11
NG	NG																		25	75					2
L	L																			5		60			10
R	R																						10	15	1
ER	ER																						0	100	7
		6	2	14	9	11	4	3	4	1		6	3	3	1	3	2	5	9	3	9		5	4	71.5%

Subject 8

Initial Consonants

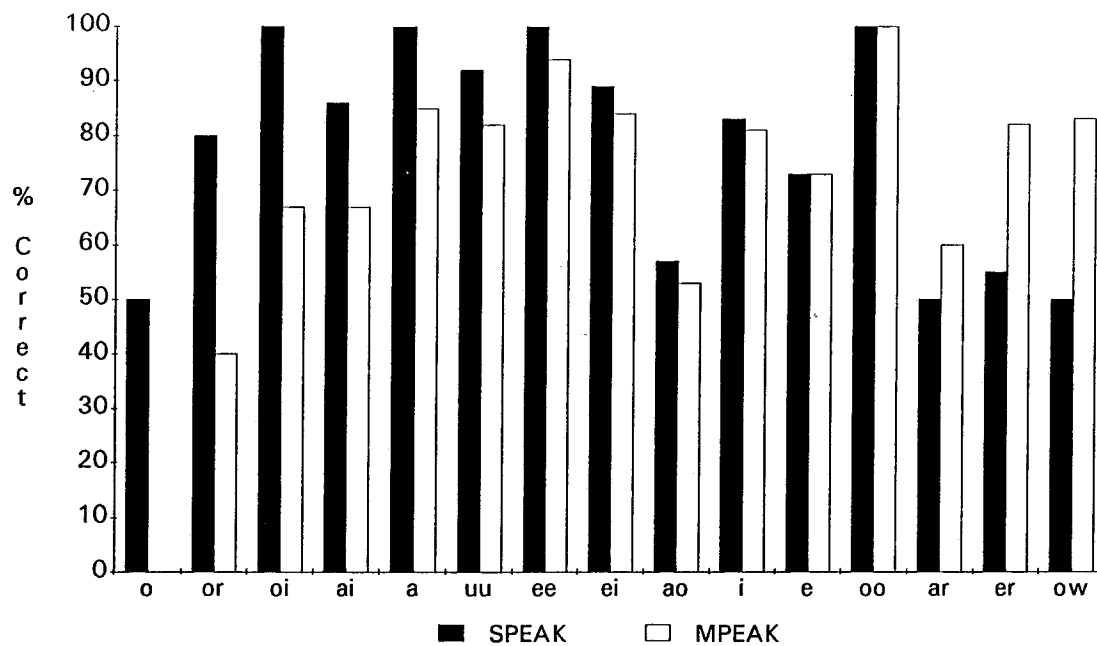


Initial Consonants

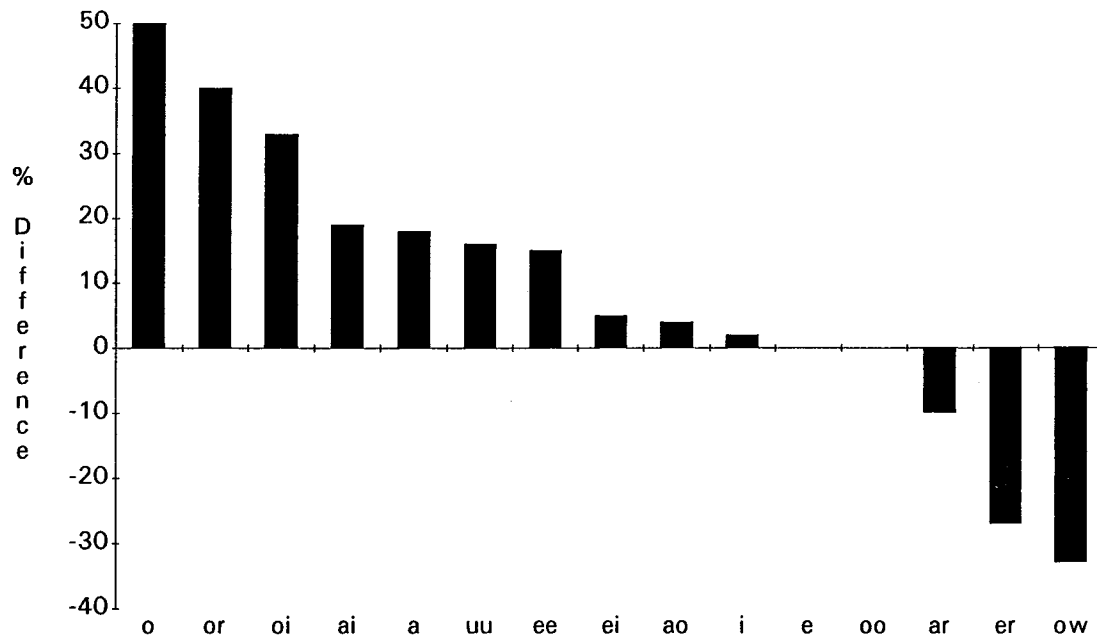


Subject 8

Medial Vowels

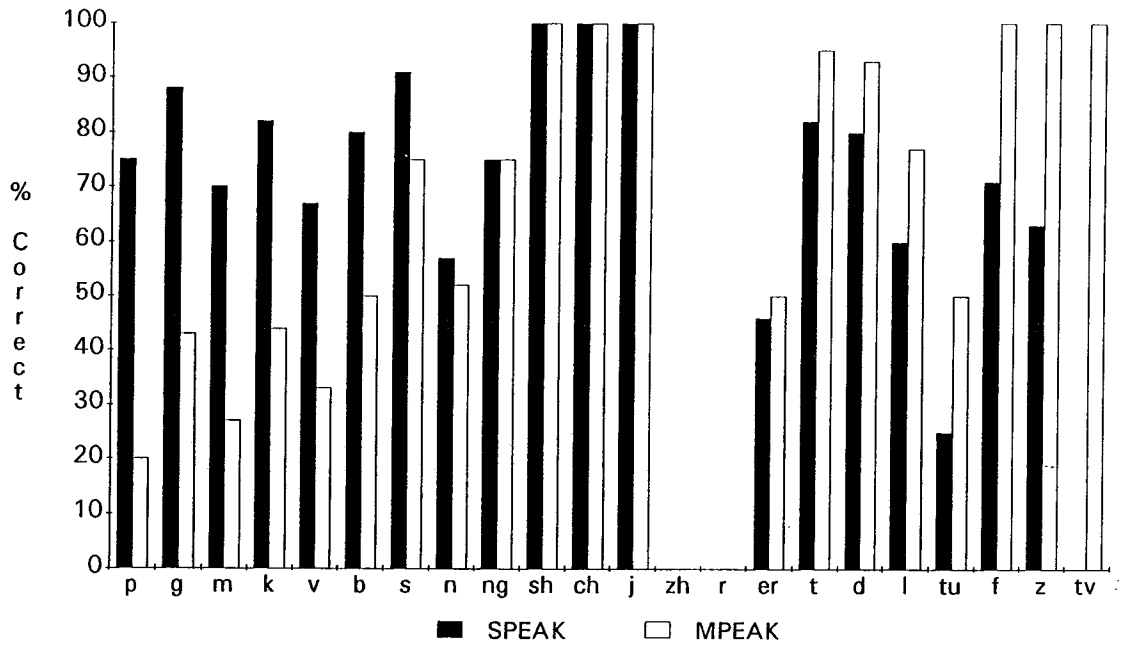


Medial Vowels

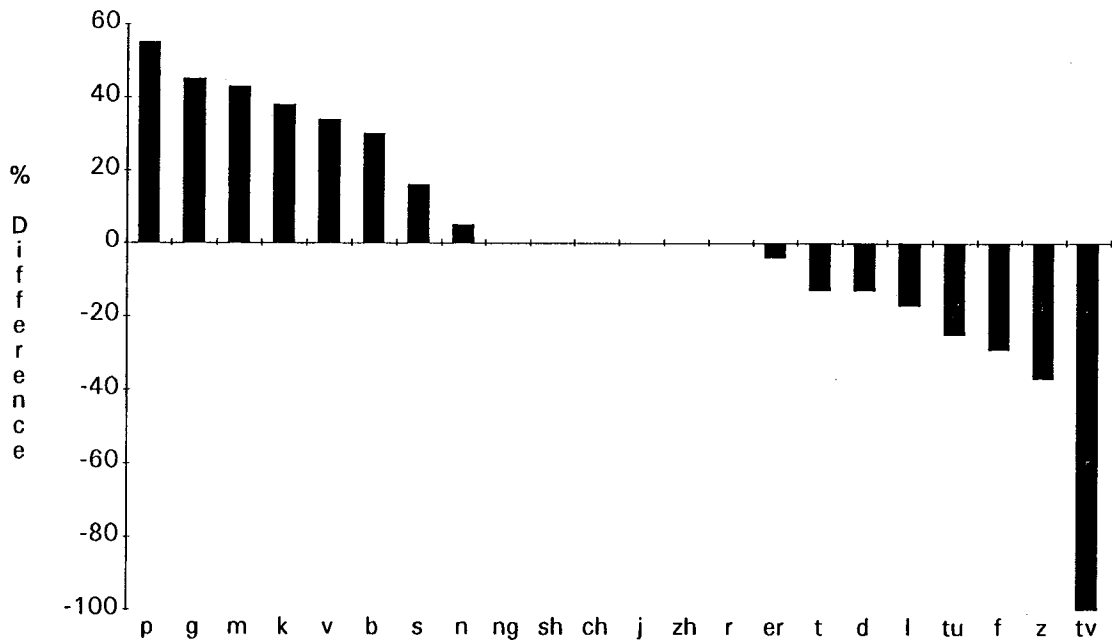


Subject 8

Final Consonants



Final Consonants



MPEAK- Raw Scores- Subject 9

Initial Consonants

		RESPONSE																				-			
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R
S T I M U S	P	5		2	1	1											1		2					1	13
	B	1	11																					1	14
	T	2		4		3						1		1			1								12
	D		5		6		1																		12
	K	1		4		7											1								13
	G		1		2		3	2													1				8
	F		1					5					1		1										9
	V		2	1					1																4
	TU		1									1													2
	TV		1										1												2
	S											7		2	1					1			1		12
	Z				1																				1
	SH												2	5											7
	CH					1							1	2	2										6
	J															3	1								5
	H				1	1	1									1	7								12
	M	1																	6					4	1
	N				1														1	2				3	1
	W		5			1													1		2				1
	WH																				1				1
Y						3												1						4	
L		1		2												1		3	1				6	15	
R	2	1		1														3					3	15	
		12	29	11	16	14	8	11	1	0	1	13	0	11	3	5	12	15	7	4	0	1	18	4	43.0%

Vowels

		RESPONSE													-									
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH		AI	OW	OI	AO					
Eve	EE	13	2																1					17
It	I	1	9	3						3	1	1											1	20
Met	E	1	1	7	2								3	1									1	16
Have	A				16						1			1									2	20
S Heart	AR			1	1									1						1				4
T Dog	O				1																			2
I Corn	OR				4						1											1		6
M Foot	OO			1						2		1	1	1	1									7
U Boot	UU	1			1						6	1												9
L Up	U			1								10												17
U Bird	ER		1	1						2	1			3	1								2	11
S Say	EI		1	2	1									13									1	20
Go	OH		2		1						2												1	14
I	AI	1	1	1	4										1							6	1	15
Out	OW			1	1										1							1		6
Boy	OI			1																				3
More	AO			2	2						1	2										1		3
		17	17	21	34	0	3	0	4	11	20	5	26	10	14	3	4	11	0					48.5%

Final Consonants

		RESPONSE																		-						
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N		NG	L	R	ER		
S T I M U S	P	3		5		1														1		1		11		
	B		3																			2		5		
	T	1		11	1	4						1					1					1		1	21	
	D		1		8	1				1											2		1		1	15
	K	2		3		10															1		1		17	
	G		1	1	2	1	1														1				8	
	F	1		1				2					2								1				7	
	V				1				2					1	1										5	
	TU			1					1				2								1				6	
	TV																								2	
	S			1									5		2		1			1	1				11	
	Z					1								6											7	
	SH			1											3										4	
	ZH														1										1	
	CH			1												1									6	
	J																3							1	4	
	M	1		1	1				1				1											2	11	
	N			1	1		2													3	11		2	1	21	
	NG				2			1												1					4	
	L			1												1					3		8	8	21	
R																							1	1		
ER	2																						6	12		
		10	5	28	16	18	3	4	4	1	0	12	9	8	0	6	3	6	25	0	19	0	19	4	43.0%	

MPEAK- % Scores- Subject 9

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	-
P	38		15	8	8											8		15						8	7
B	7	79						7															7		7
T	17		33		25					8		8				8									6
D		42		50		8																			6
K	8		31		54											8									7
G		13		25		38	25																		4
F		11				56				11		11						11							5
V		50	25					25																	2
S		50							0		50														1
TU		50																							1
TV		50																							1
S										58		17	8					8				8			6
TU											0														1
TV																									1
S																									6
TU																									1
TV																									1
S																									6
TU																									1
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TU																									1
TV																									

SPEAK- Raw Scores- Subject 9

Initial Consonants

		RESPONSE																										
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH	Y	L	R	-			
S T M U S	P	10		1																						2	13	
	B		13																									13
	T			10																								11
	D	1			12																							12
	K					13													1									14
	G						9																					9
	F							6																				8
	V		1															1										3
	TU										1																	2
	TV											1																2
	S												14															14
	Z													1														0
	SH														6													7
	CH															7												7
	J																8											8
	H																	9										12
	M																		7									11
	N																			2								9
W																				8							10	
WH																					7						4	
Y																						2					1	
L																							1				1	
R	1	2																						1	8		15	
		12	19	11	14	15	11	6	0	1	1	15	0	6	7	8	10	10	13	9	1	2	13	13	3	82.0%		

Vowels

		RESPONSE																		
		EE	I	E	A	AR	O	OR	OO	UU	U	ER	EI	OH	AI	OW	OI	AO		
S T M U S	Eve	EE	10	1																17
	It	I	2	20		1								6						23
	Met	E		2	11							1								14
	Have	A			1	19									1					21
	Heart	AR					4													4
	Dog	O																	1	1
	Corn	OR			1	1				1		1								4
	Foot	OO								2										2
	Boot	UU									9				2				1	12
	Up	U		2	2							9			4					17
	Bird	ER					2	2		1			7							12
	Say	EI												18						18
	Go	OH													15					15
	I	AI														14			1	15
	Out	OW			1				1						1		2		1	6
Boy	OI																2		2	
More	AO							1										14	17	
		12	25	16	21	6	2	3	3	9	11	7	25	24	14	2	2	18	0	78.5%

Final Consonants

		RESPONSE																									
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L	R	ER	-			
S T M U S	P	7		1	1	2																				11	
	B		5		1																						6
	T	1		20		1																					22
	D				13		1																				15
	K					2	16																				18
	G							6																			7
	F								4																		6
	V									1	2														1		6
	TU											1															5
	TV																			1							1
	S													12													12
	Z													1	5												7
	SH															4											4
	ZH																										0
	CH																	6									6
	J																		4								4
	M																			7	2				1		10
	N																			4	9			1	4	1	22
NG																					2				1	4	
L																							16	1	1	21	
R																										0	
ER																							3	10		13	
		8	7	26	22	20	8	6	4	1	0	13	5	4	0	6	5	12	11	2	20	0	16	4	74.5%		

SPEAK- % Scores- Subject 9

Initial Consonants

	RESPONSE																								
	P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	CH	J	H	M	N	W	WH		Y	L	R	
P	77		8																					15	
B		100																							7
T	9		91																						6
D				100																					6
K					93																				7
G						100											7								5
F		13					75									13									4
V		33		33				0																	2
TU		50							50																1
TV		50								50															1
S											100														7
Z												14													NP
SH													86												4
CH														100											4
J															100										4
H				8												75									6
M					9												64	18							6
N						11												89						9	5
W																			70						5
WH																			50	25					2
Y																					100				1
L	7	13			7																	7	53		8
R																							7	87	82.0%
	6	10	6	7	8	6	3	1	1	8	3	4	4	5	5	7	5	1	7	7	2				

Vowels

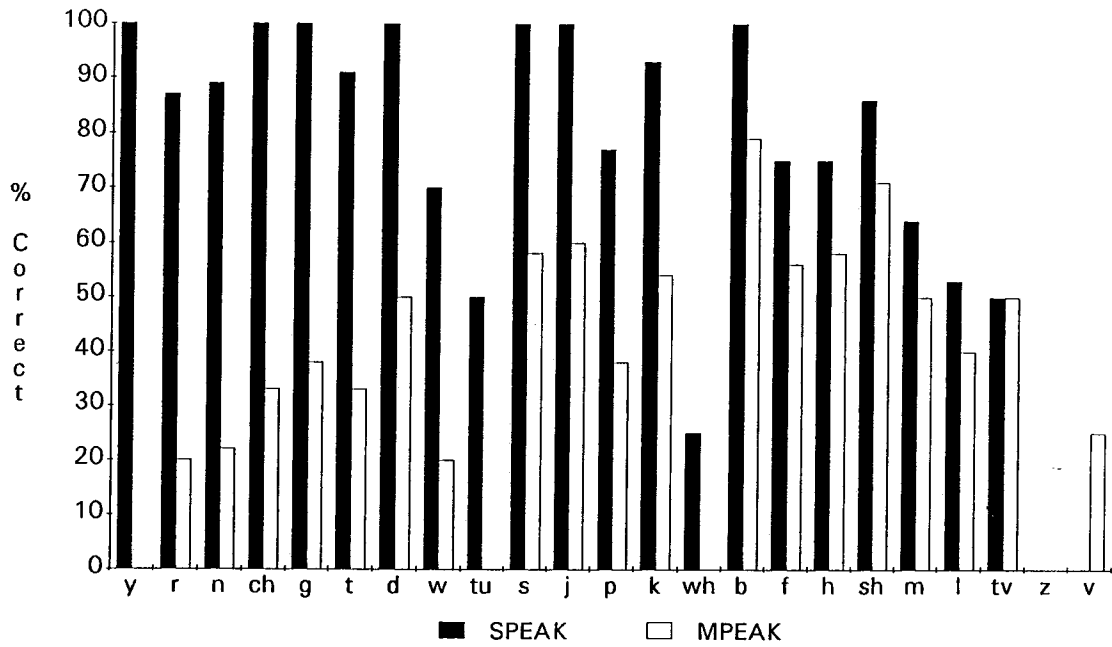
		RESPONSE																						
		EE	I	E	A	AR	AR	OR	OO	UU	U	ER	EI	OH	AI		OW	OI	AO					
Eve	EE	59	6																			35		9
It	I	9	87		4																			12
Met	E		14	79							7													7
Have	A			5	90									5										11
Heart	AR					100																		2
Dog	O						0																100	1
Corn	OR			25	25				25		25													2
Foot	OO									100														1
Boot	UU										75												8	6
Up	U		12	12								53			17									9
Bird	ER					17	17			8			58		24									6
Say	EI													100										9
Go	OH														100									8
I	AI															93							7	8
Out	OW			17					17						17		33						17	3
Boy	OI																	100						1
More	AO									6						12							82	9
		6	13	8	11	3	1	2	2	5	6	4	13	12	7	1	1	9						78.5%

Final Consonants

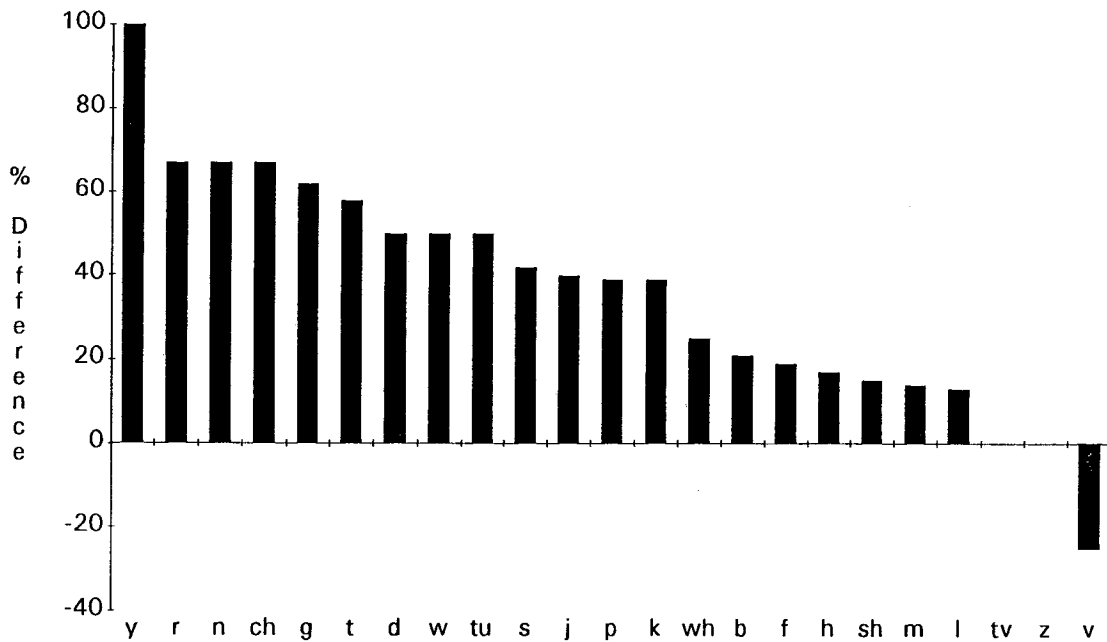
		RESPONSE																							
		P	B	T	D	K	G	F	V	TU	TV	S	Z	SH	ZH	CH	J	M	N	NG	L		R	ER	
P		64		9	9	18																			6
B			83		17																				3
T		5		91		5																			11
D			7		87		7																		8
K				11		89																			9
G					14		86																		4
F			33					67																	3
V				33				17	33																3
TU					20	20	20		20																3
TV										0															1
S											100														6
Z												14	71												4
SH														100											2
ZH																									NP
CH															100										3
J																100									2
M																	70	20							5
N					9				5								18	41			5				11
NG						25													50					25	2
L		5		5						5												76	5	5	11
R																									NP
ER																							23	77	7
		4	4	13	11	10	4	3	2	1	7	3	2	3	3	6	6	1	10						74.5%

Subject 9

Initial Consonants

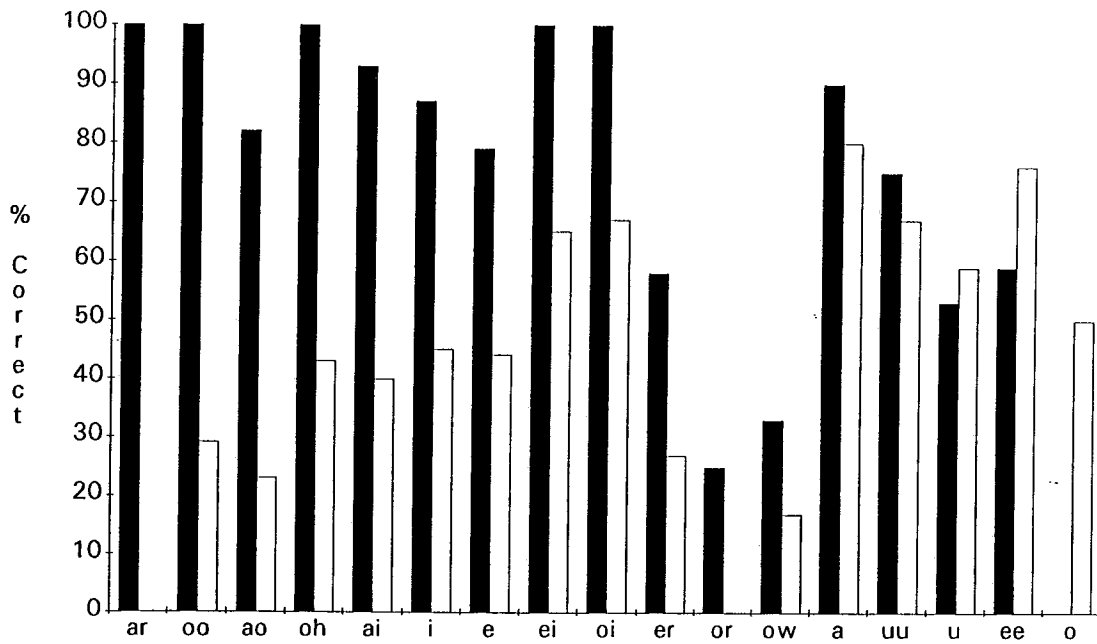


Initial Consonants

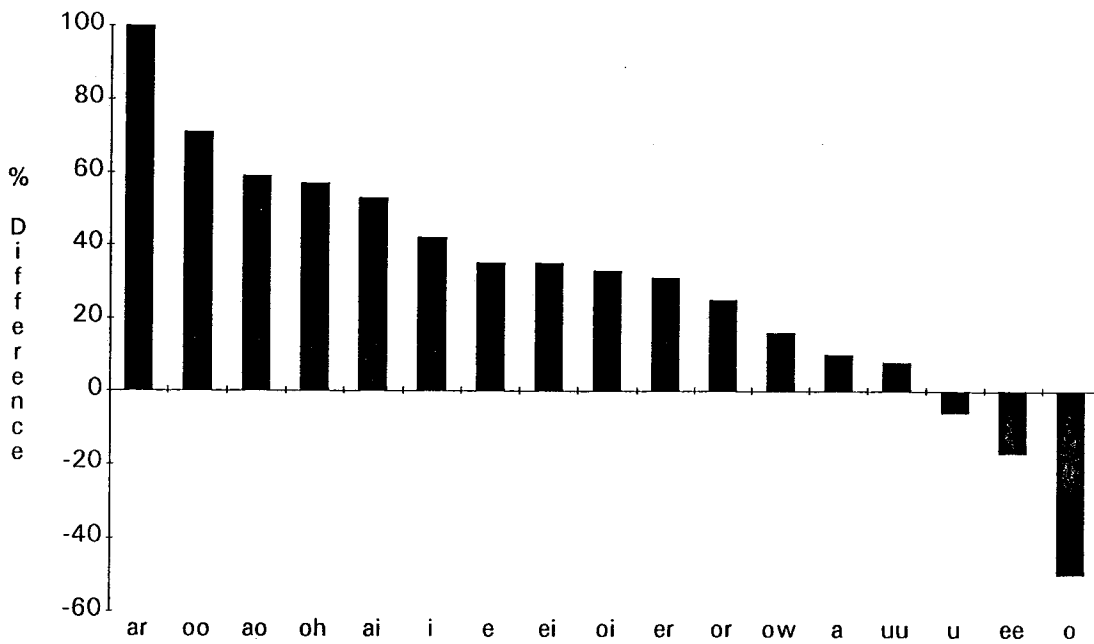


Subject 9

Medial Vowels

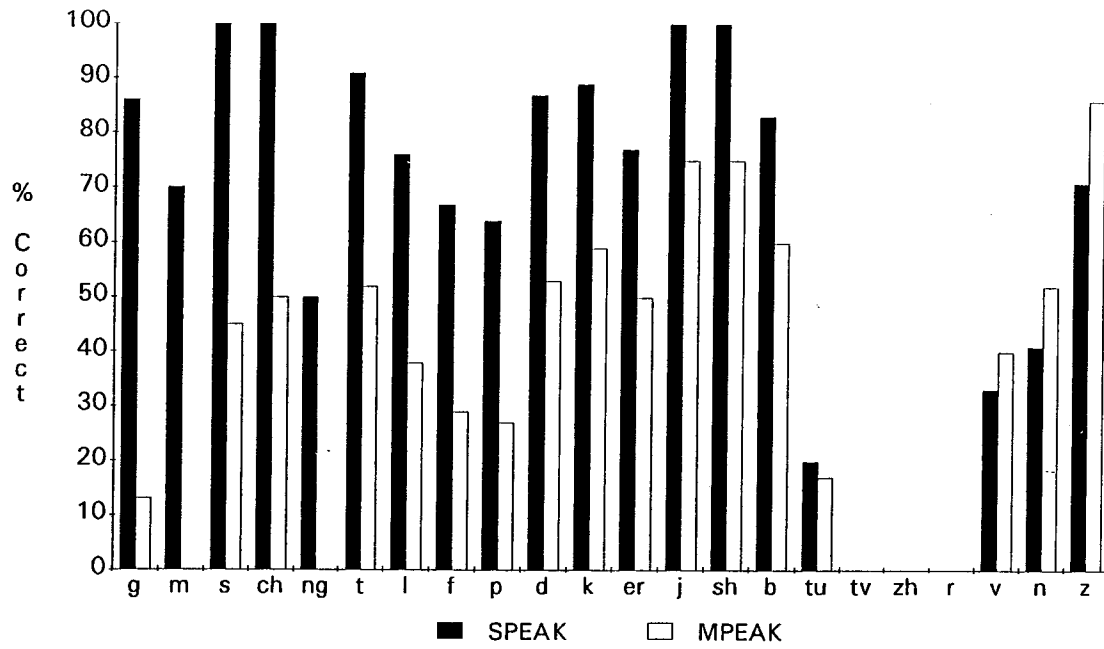


Medial Vowels



Subject 9

Final Consonants



Final Consonants

