Evaluation of Low Data Rate Voice CODECS for Air Traffic Control Applications

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15. Supplementary Notes

16. Abstract

This report describes the test objectives, methodologies, and results of pre-qualification testing and evaluation of various 4.8 and 2.4 kilo bit per second (kbps) compression rate voice coder/decoders (CODECS) that are being considered for the use in supporting the Federal Aviation Administration's (FAA's) satellite communications technology demonstration program.

The principal objectives of this program are to evaluate the performance of these CODECS for potential air traffic applications and to develop CODEC testing procedures tailored to the specific needs of air traffic control (ATC) communications.

This report concludes with a description of the relative performance and ranking of the CODECS tested. This information has led to the selection of a quantity of 4.8 and 2.4 kbps CODECS for more comprehensive testing under simulated background noise and satellite channel noise conditions in the CODEC Test Bed Facility.

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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) is evaluating the use of digitized voice for air-to-ground air traffic control (ATC) traffic. This technique offers the promise of being able to reduce some of the adverse affects of voice transmission media on the quality of the voice traffic. By digitizing the voice, the apparent quality of the voice signals will be more consistent for the ATC controller.

In support of this effort, preliminary tests were conducted in August 1988 on a number of commercially available digital voice coder/decoders (CODECS). This report contains preliminary results of the tests which were conducted on CODECS from a number of manufacturers using air traffic controller personnel from the New York ATC facility in Long Island as listeners.

The tests were based on a series of standardized messages digitized by the various CODECS. The subsequently reconstructed voice messages were recorded and replayed for the controllers who made subjective assessments of the quality of each message. The test results were evaluated with the objective of identifying the better performing (CODEC) of the test lot for further study.

The best performing CODEC was the 9.6 kilo bit per second (kbps). The best 4.8 kbps CODEC was ranked slightly lower than the 9.6 kbps CODEC indicating potential use of 4.8 kbps for ATC applications.

1. TEST PROGRAM OBJECTIVES.

The principal objective of the tests was to evaluate the performance of various coder/decoders (CODECS) for use in an air traffic control (ATC) environment using air traffic controllers.

1.1 BACKGROUND.

Voice CODECS are being considered for use in air-to-ground communications via satellite. As there are a large number of CODEC manufacturers in the market, there is a need to identify the highest performing low data rate models for further consideration. The lower data rate is sought due to the resulting improvements in the radio frequency (RF) link power budget. This, in turn, can ultimately affect the cost of implemented systems. During the tests the CODECS were evaluated for intelligibility as well as acceptability on the part of ATC personnel.

Although low data rate CODECS may be used with some degradation in the telephony environment, their use in the ATC environment must not be allowed to jeopardize air safety. In order to address the numerous subjective performance issues associated with the use of voice CODECS, air traffic controllers were used to conduct subjective listening tests. The results of this initial test program are intended to lead to more rigorous evaluations of a smaller number of CODEC models in the near future. Such tests will study the performance under high noise environments and address a number of technical issues such as the voice power spectrum of reconstructed voice signals.

2. TEST METHODOLOGY.

Testing conducted in this initial phase of the CODEC evaluations placed minimum operational stress on the CODECS and did not involve noisy environments or noticeably accented voices, both of which can place additional constraints on the usefulness of voice digitizing, low data rate CODECS. Therefore, the tests helped only to identify the CODECS that have acceptable voice processing algorithms under ideal operating conditions.

ATC controllers were used for the tests as opposed to professional "listeners," who are typically oriented to telephony performance evaluation. ATC voice traffic characteristics vary from those of normal telephony. The intelligibility requirements are very high in the ATC environment. Further, traffic is largely "in context" or anticipated by the controllers which can bias the intelligibility of a message. Thus, it is necessary to evaluate the CODECS with a focus on ATC services.

Controllers are well trained in working over circuits with considerable degradation. The types of signal impairments experienced by many of them to date differ, however, from the types of impairments experienced through digital voice CODECS. There is some question concerning the subjective sensitivity of controllers to CODEC performance with and without noise impairments. This suggests that controllers be used for future listening tests.

2.1 TEST PROCEDURES.

Two types of messages were used for the tests. One type was taken from a set of standard phonetically balanced voice messages known as Dynamic Acceptability Measurement (DAM). A second type of message consisted of recordings of actual ATC voice traffic recorded at the Leesburg ATC facility. The test material and evaluation forms are presented in the appendix. The use of ATC voice traffic is considered more pertinent to the present evaluation of CODECS. Also, the use of the two types of messages will help to relate the results of independent tests by others for telephony applications to the ATC environment.

The test voice messages used for the tests were recorded on a high quality audio cassette. Copies of the cassette were submitted to a number of CODEC manufacturers, who, in turn, processed the test messages through their CODEC. The processed voice messages were then assembled in a test sequence for replaying to the test controllers. The test messages are grouped into 16 sets of several sentences each. Each set had previously been processed through 14 CODECS. The entire set of resulting test messages consists of 240 digitized/reconstructed messages plus the set of 16 original, unprocessed voice messages. These 256 sets were then randomly rearranged and played to the listening audience of ATC controllers.

The principal performance issue of CODECS as related to use by ATC personnel is intelligibility. Also of importance is acceptability on the part of the controllers. Voice that is digitized into low data rates signals, i.e., 4800 bits per second (bps), has a "signature" or audio character that may or may not be burdensome to the controller. The test controllers were, therefore, asked to score both the intelligibility and acceptability of each test message. Although not rigorous, the scoring system does provide results suitable to rank the various CODECS in order of utility in the ATC environment.

In the tests, CODEC models G and L were inserted to provide control messages. Model G is the original, unprocessed voice. Model L is a 9.6 kilobit (kb) CODEC with near "toll quality telephone" performance characteristics.

The tests were conducted at the New York ATC facility during early August 1988. Appendix A contains a transcript of the voice test messages, test procedure details, and a sample of the scoring sheets used to record test result. The testing took about 1 hour and 20 minutes plus break periods approximately every half hour.

3. EVALUATION OF TEST RESULTS.

3.1 SUMMARY OF TEST RESULTS.

The total number of discrete scores recorded are 3840 for intelligibility and 3840 for acceptability. That is, 16 listeners scored 16 messages through 15 CODECS. These are summarized in figure 1. The figure shows the average intelligibility and acceptability scores for all CODECS. CODEC F had the highest scores of the 4.8 and 2.4 kb CODECS.

3.2 ACCEPTABILITY SCORES VS. INTELLIGIBILITY SCORES.

Figure 2 shows the intelligibility and acceptability scores for all CODECS in order of scores. Both types of scores tend to rank the CODECS in the same order. The correlation of the intelligibility and acceptability scores can be seen in figure 3. It can be concluded that the listeners were in close agreement between intelligibility and acceptability scores.

3.3 DATA INTEGRITY.

The validity of a set of subjective test data can often be validated by assessing the distribution of the data. The distribution of intelligibility scores is shown in figure 4. This figure shows the standard deviation of listener scores for each message-CODEC test. There are 240 points in the graph representing 15 CODECS times 16 message sets. The data points appear to be approximately a (Gaussian) distribution around a mean of 0.7 score points (0.7 out of a range of 5.0 suggests reasonable integrity for this type of testing).

Figures 5, 6, and 7 show the average deviation for each listener from the group's average score during the testing. Listeners 1 and 5 seem to have changed their general attitude during the test from one extreme to the other. Listener 11 remained optimistic throughout the period. In paragraph 3.4 below further consideration is given to these anomalies.

Further confirming the validity of the test results are the standard deviation of intelligibility scores shown in figure 8 by CODEC model. The deviation per quarter of the testing period for each CODEC is a fairly narrow range. It is noted that the deviation of opinions is lowest for the clear, unprocessed voice.

3.4 EVALUATION BY MESSAGE TYPE.

Figure 9 shows the intelligibility scores as a function of message type. In general, female voices were rated lower. Likewise, ATC messages received lower scores than the standard DAM messages. This is a non-trivial point, since evaluation by DAM messages alone will probably not produce test results indicative of the performance in an ATC environment. Figure 10 further confirms this by showing that unprocessed DAM messages score higher than unprocessed ATC messages. The higher score of DAM messages for clear voice indicates that ATC messages may be inherently more difficult to understand.

Figures 11 and 12 show that the listener group had a high degree of agreement on the scoring of message 13. Message 13 is a female speaker giving an ATC message. This further substantiates the importance of using ATC voice traffic for the CODEC tests. Figure 13 compares ATC and DAM messages through the various CODECS. In some cases there is a significant difference between the ATC and DAM messages. See CODEC "N" where message 13 scores 1.3 versus 2.8 for DAM messages.

3.5 EVALUATION BY CODEC/MESSAGE TYPE.

Figure 14 shows the intelligibility scoring for each CODEC versus speaker gender and message type during each of the four quarters of the test period. This demonstrates that each manufacturers algorithm will handle voice differently

depending on the characteristics of the message. These test evaluations will be used to help structure subsequent CODEC tests.

3.6 EVALUATION BY TEST LISTENER.

Figure 15 shows the variation of intelligibility scores as a function of listener years of experience. A similar curve of acceptability scores (not included) shows essentially the same results. The figure shows a slight tendency for personnel in the middle of the range to have higher intelligibility scores. Figure 16 is based on the same data used to generate figure 15, but separates the data by gender of the speaker. From the figure it becomes evident that the gender of the speaker does not significantly affect intelligibility versus age of the listener.

The listeners varied in average score as seen in figure 17. For example, listener 11 (49 years of age) had a significantly higher average score for both intelligibility and acceptability messages.

A question of data integrity is suggested by the variations in performance by listeners. Figures 18 and 19 show the scores for intelligibility and acceptability using a subset of the listeners. To establish this subset, the listeners in the middle age group were selected. As much as half a point difference can be seen between this group and the overall group. This suggests that toleration of CODECS by ATC personnel may vary significantly.

4. CONCLUSIONS.

Coder/decoder (CODEC) models F (4.8 kilo bit per second (kbps)), A (4.8 kbps), B (4.8 kbps), and D (4.8 kbps) are the highest ranked CODECS as being most acceptable to air traffic controllers. These can be further studied in depth for performance under more stressful operating conditions, for example, various bit error rates, high background multiple speaker, and non-speech sound levels.

5. RECOMMENDATIONS.

The principal, industry-wide issue of performance among digitizing coder/decoders (CODECS) is immunity to non-voice interference. Audio background noise can seriously affect the performance of a CODEC. If a processing algorithm does not properly account for impulse as well as steady state background noise, voice intelligibility can be easily degraded. Further studies should evaluate CODECS F, A, B, and D under various noise conditions. Robustness of these CODECS may or may not be well correlated to overall scores achieved in this initial testing phase. CODEC models H, K, N, and I can be held in reserve should the initial set prove to be unsuitable for air traffic control (ATC) use.

A CODEC's processing algorithm should also consider digital transmission error rates. Error correcting functions can add several decibels (dB) of dynamic range to a communications link. Tests should be conducted with bit error rates on the communications circuit of up to 10^{-2}. This should be accomplished using the CODEC test bed facility during the next phase of testing.

The issues of noise as well as voice pattern degradation should be analyzed for any CODEC implemented in the ATC environment. The dominant criteria for acceptance, however, should remain the subjective measure of intelligibility by

ATC personnel. More comprehensive testing methodology should be developed for the next set of CODEC tests which adds noise and multi-talker background interference to more realistically simulate the real environment.

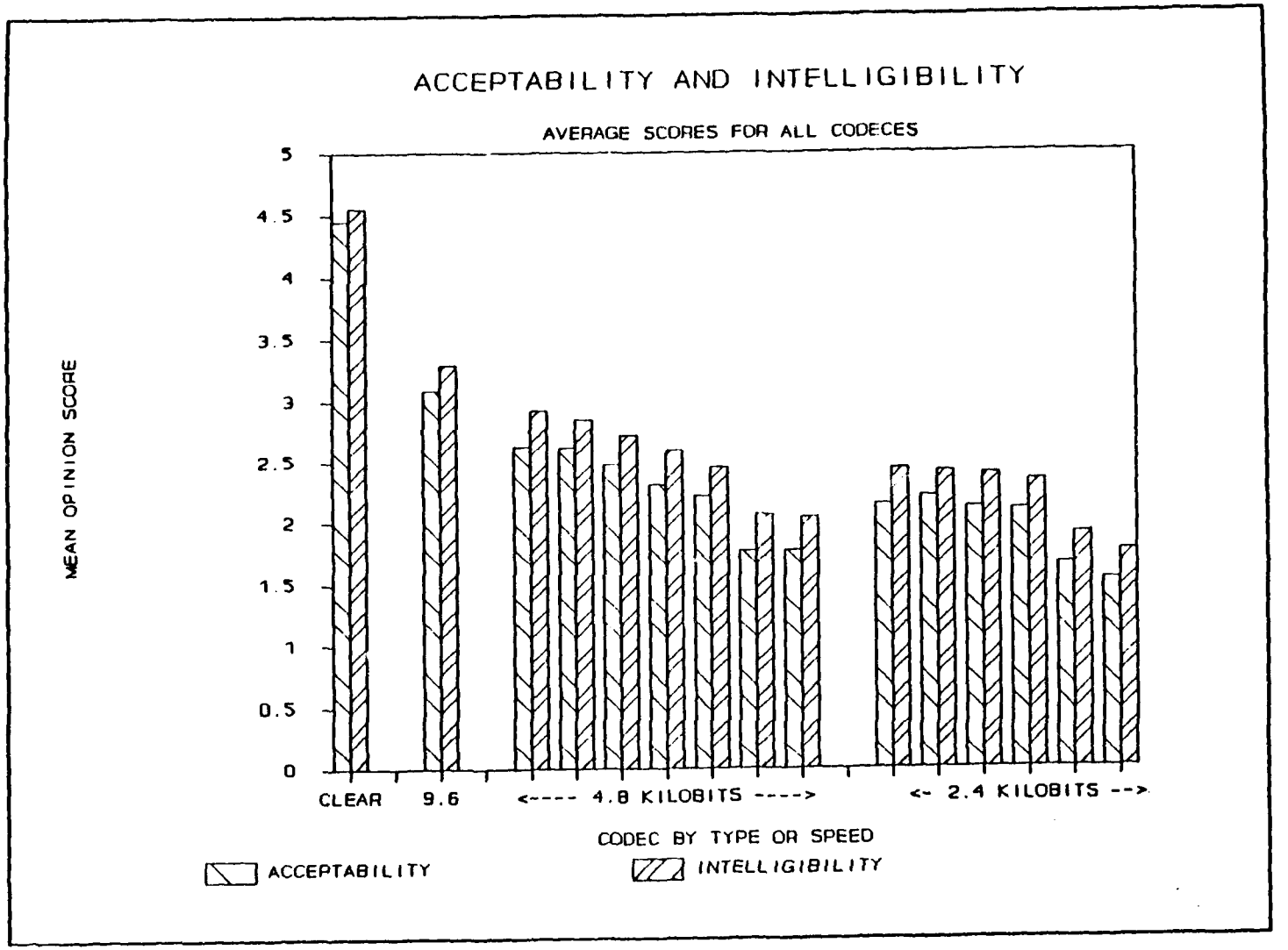

FIGURE 1. ACCEPTABILITY AND INTELLIGIBILITY (AVERAGE)

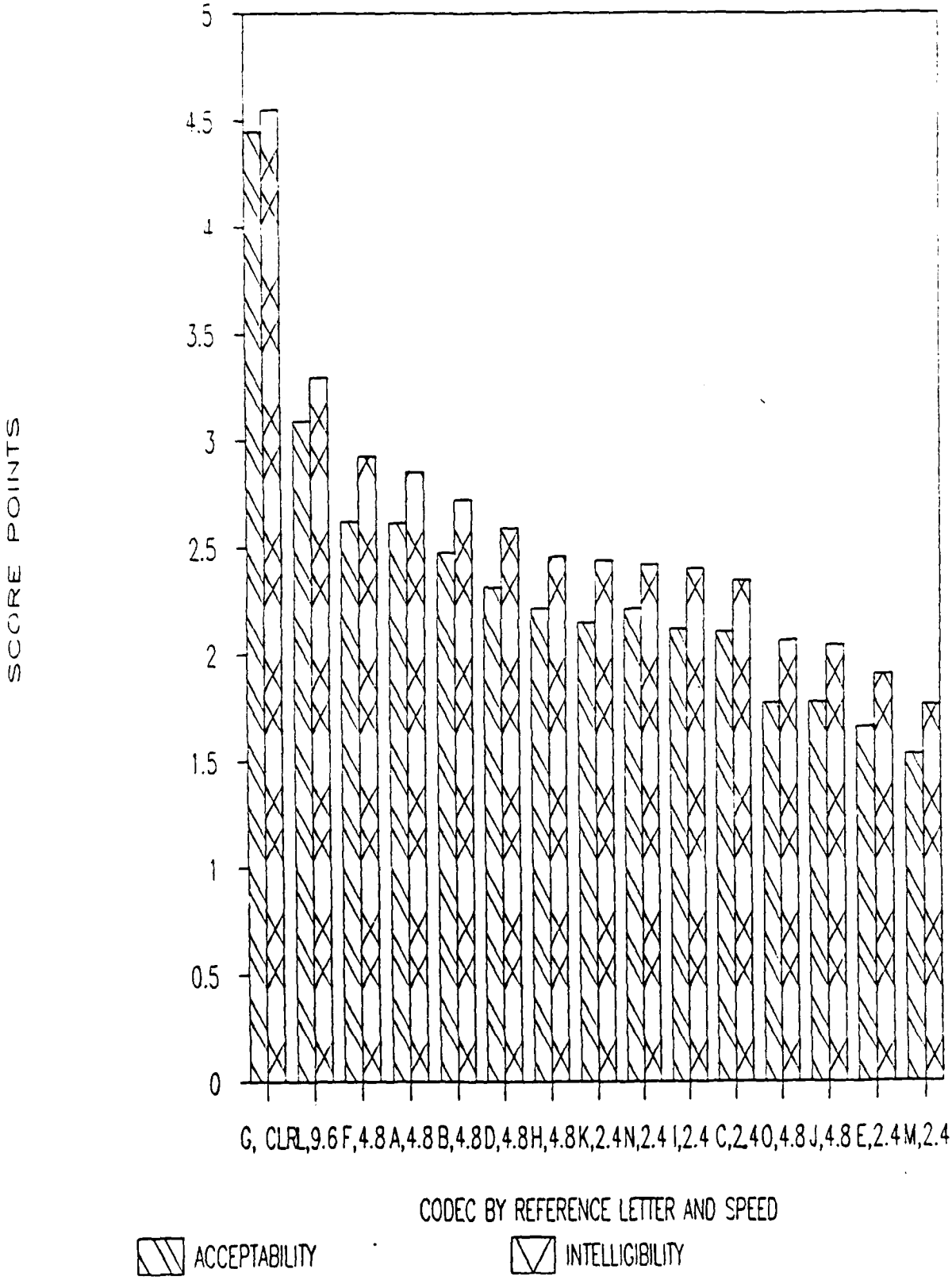

FIGURE 2. ACCEPTABILITY AND INTELLIGIBILITY (INDIVIDUAL)

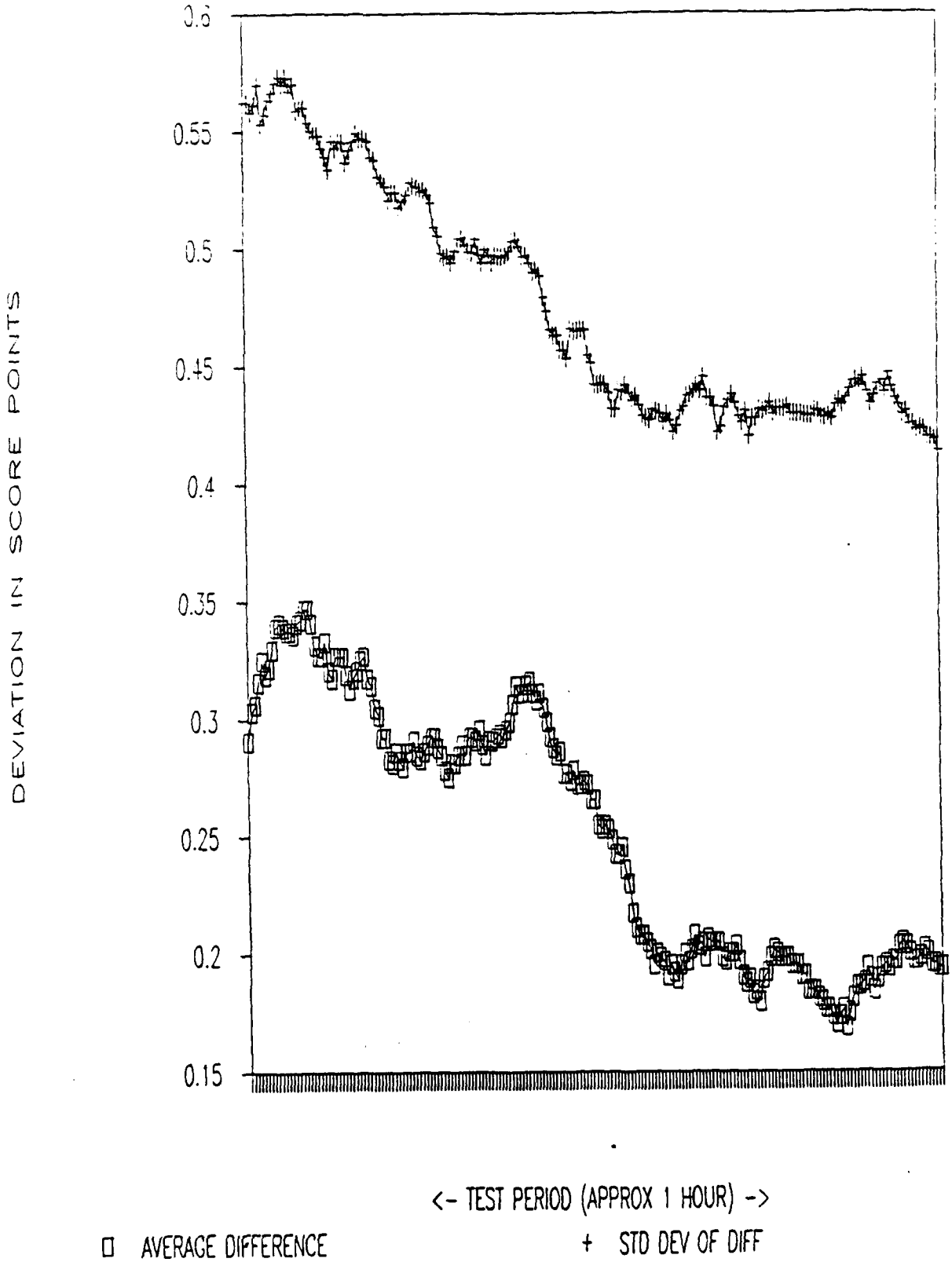

FIGURE 3. COMPARISON OF INTELLIGIBILITY TO ACCEPTABILITY

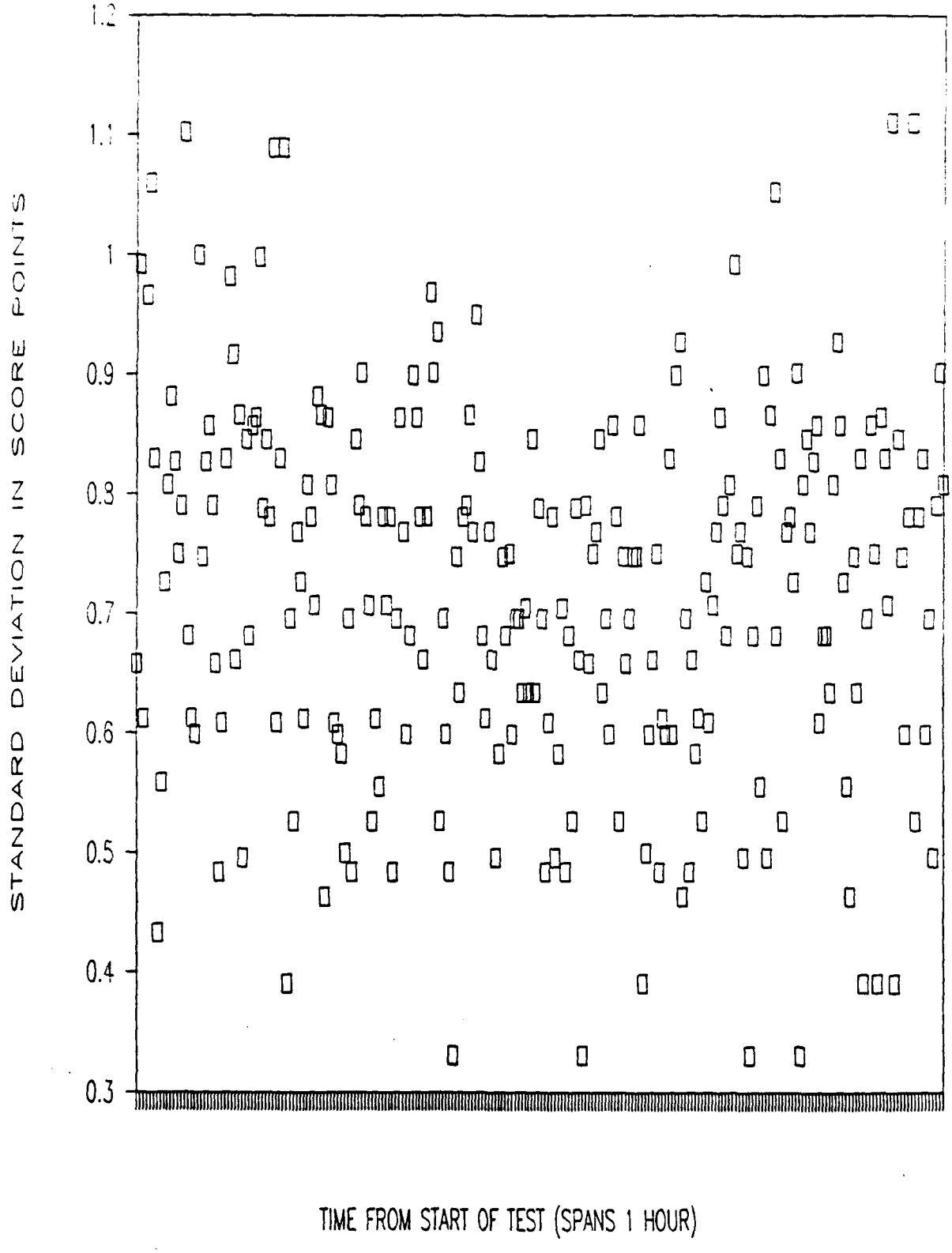

FIGURE 4. STANDARD DEVIATION OF INTELLIGIBILITY SCORES

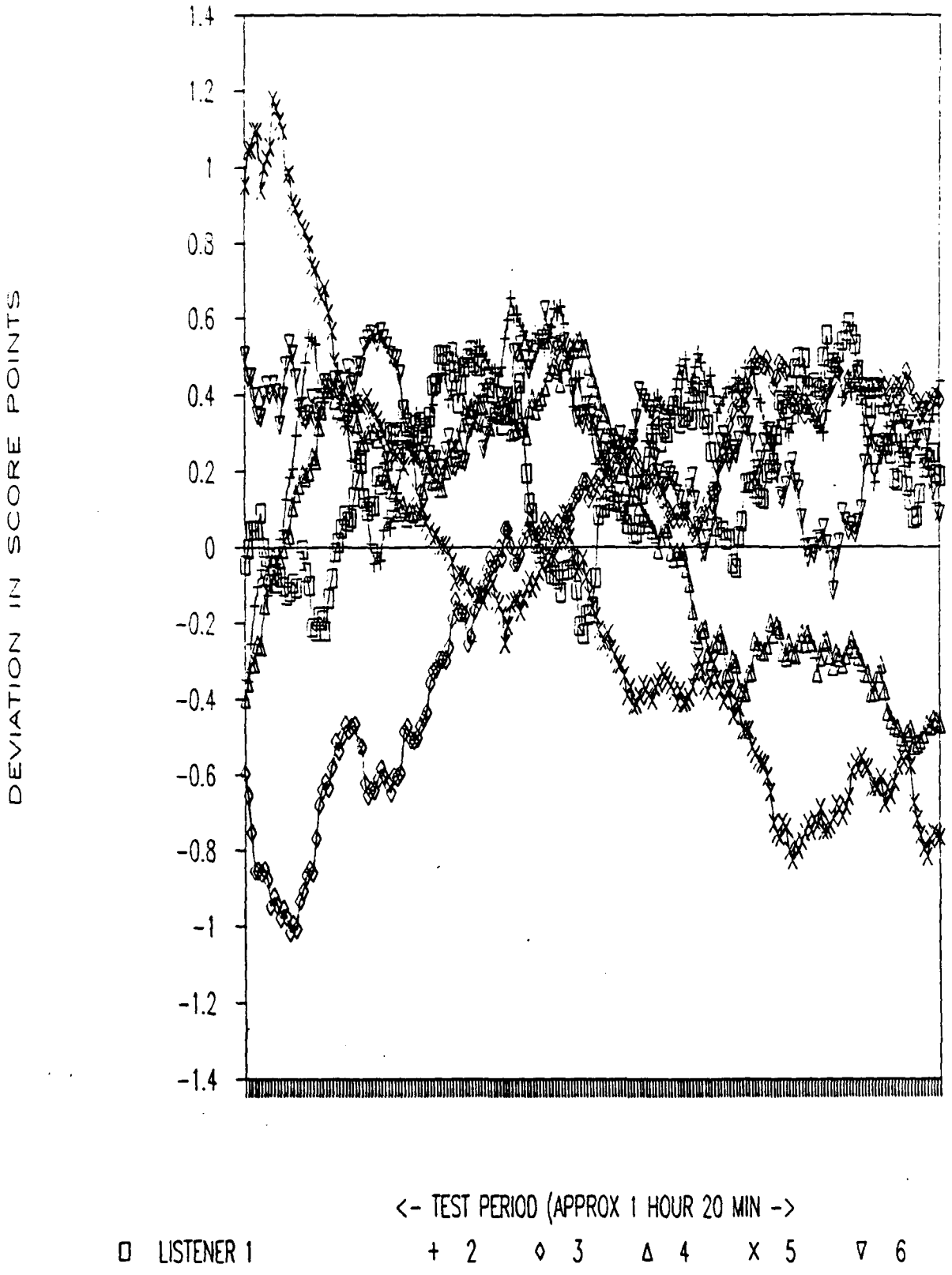

FIGURE 5. AVERAGE DEVIATION OF INTELLIGIBILITY SCORES FROM GROUP AVERAGE (1-6)

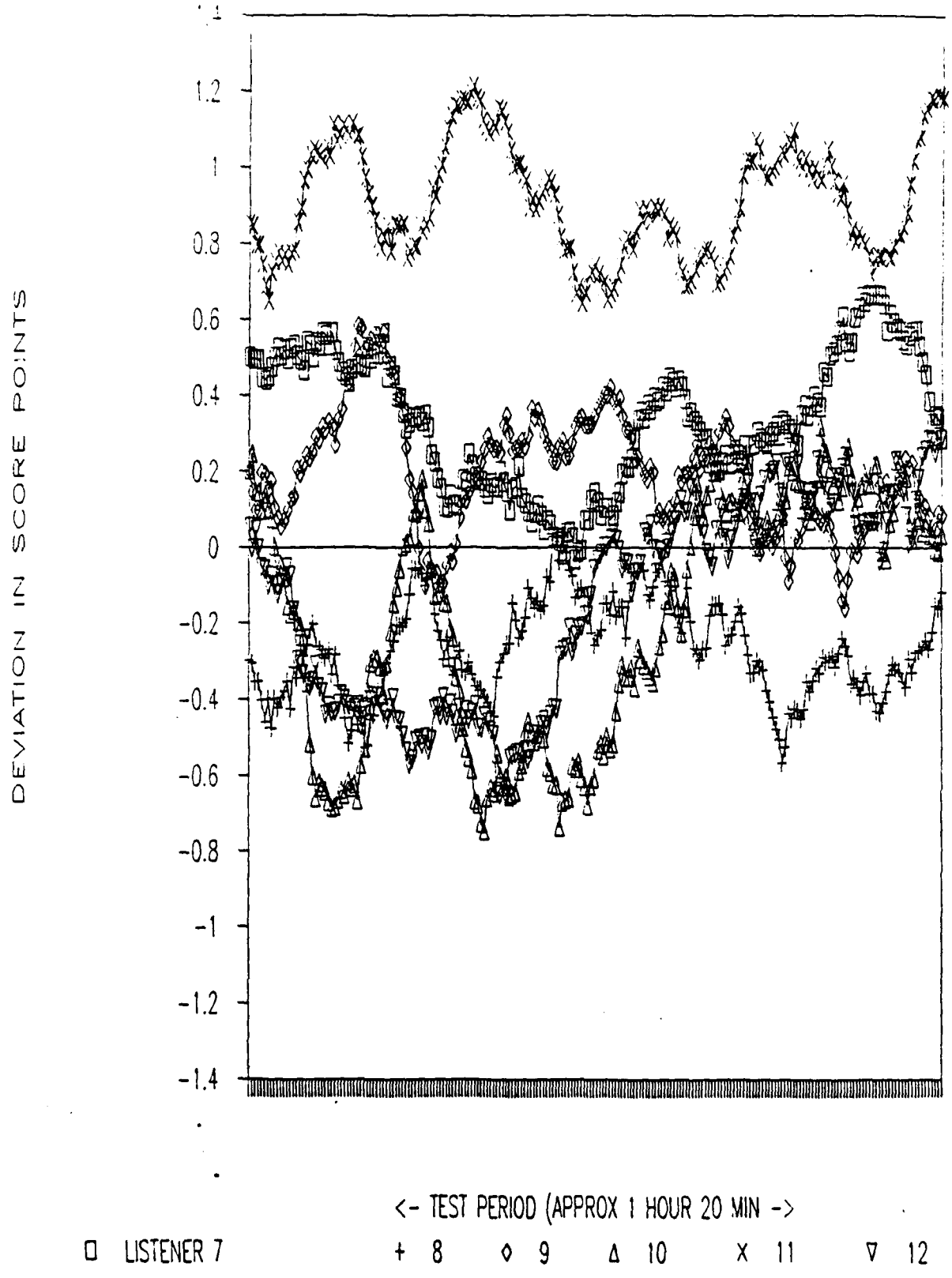

FIGURE 6. AVERAGE DEVIATION OF INTELLIGIBILITY SCORES FROM GROUP AVERAGE (7-12)

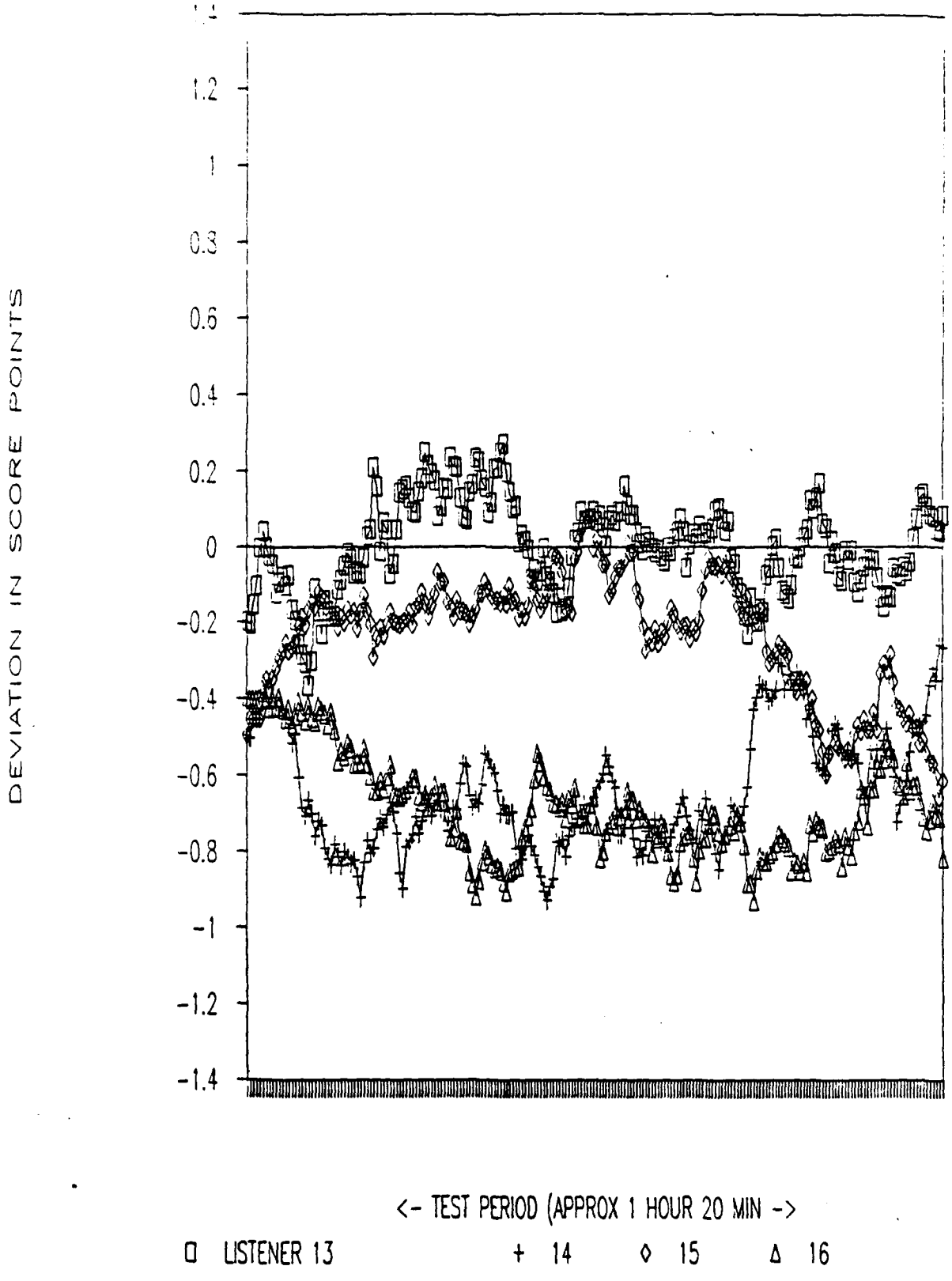

FIGURE 7. AVERAGE DEVIATION OF INTELLIGIBILITY SCORES FROM GROUP AVERAGE (13-16)

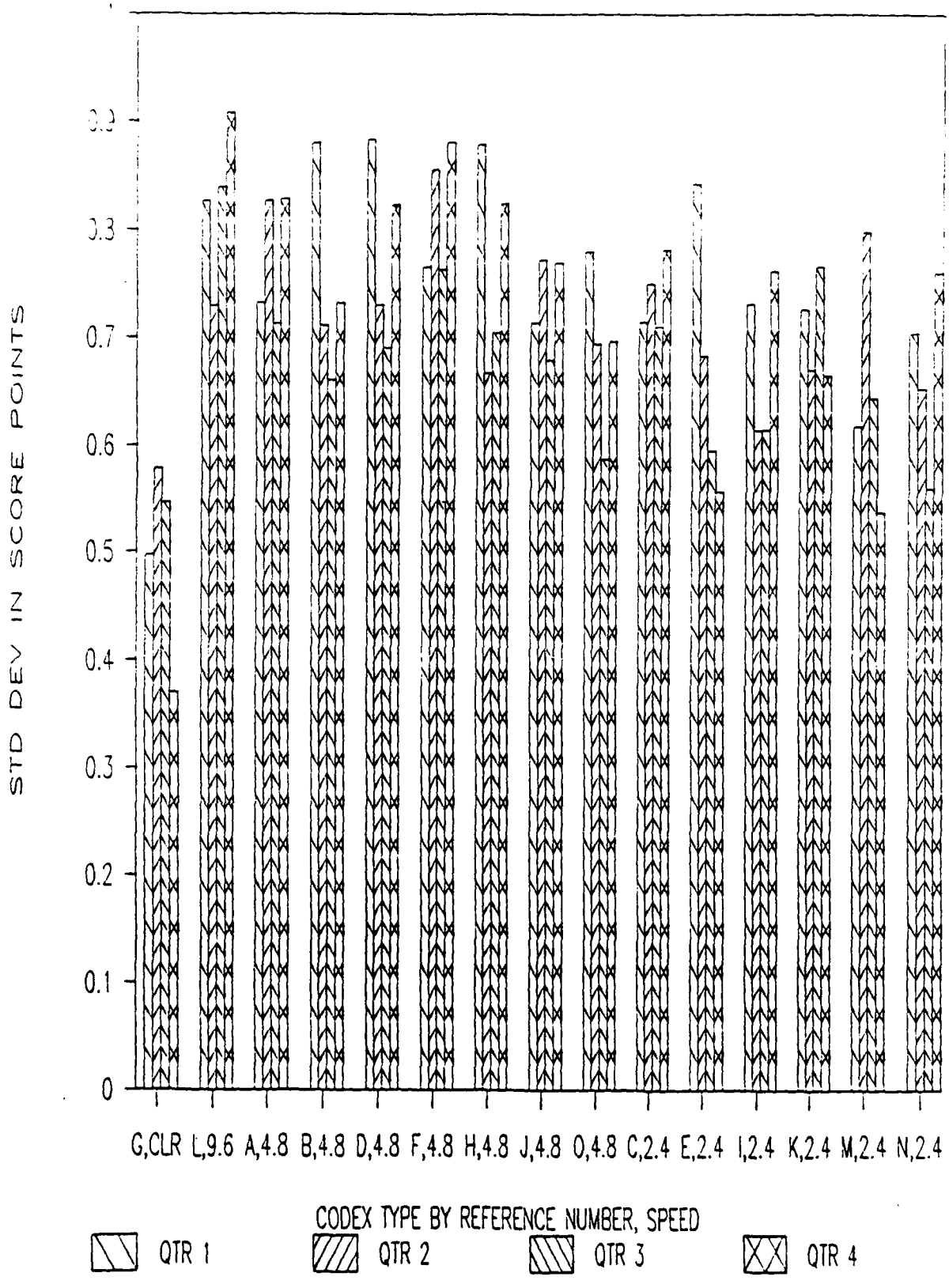

FIGURE 8. STANDARD DEVIATION OF INTELLIGIBILITY SCORES VS. TEST PERIOD

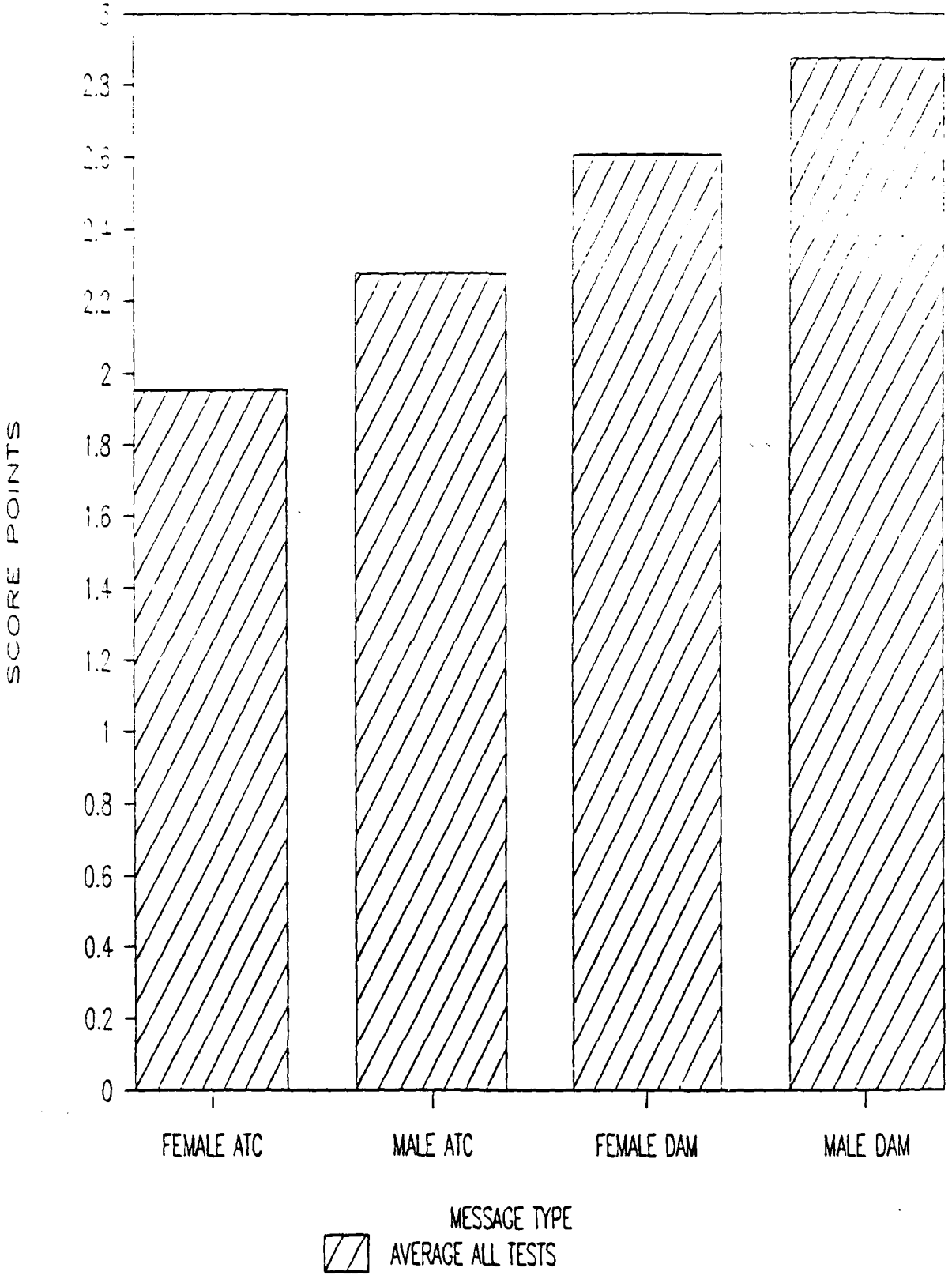

FIGURE 9. INTELLIGIBILITY SCORES (AVERAGE ALL TESTS)

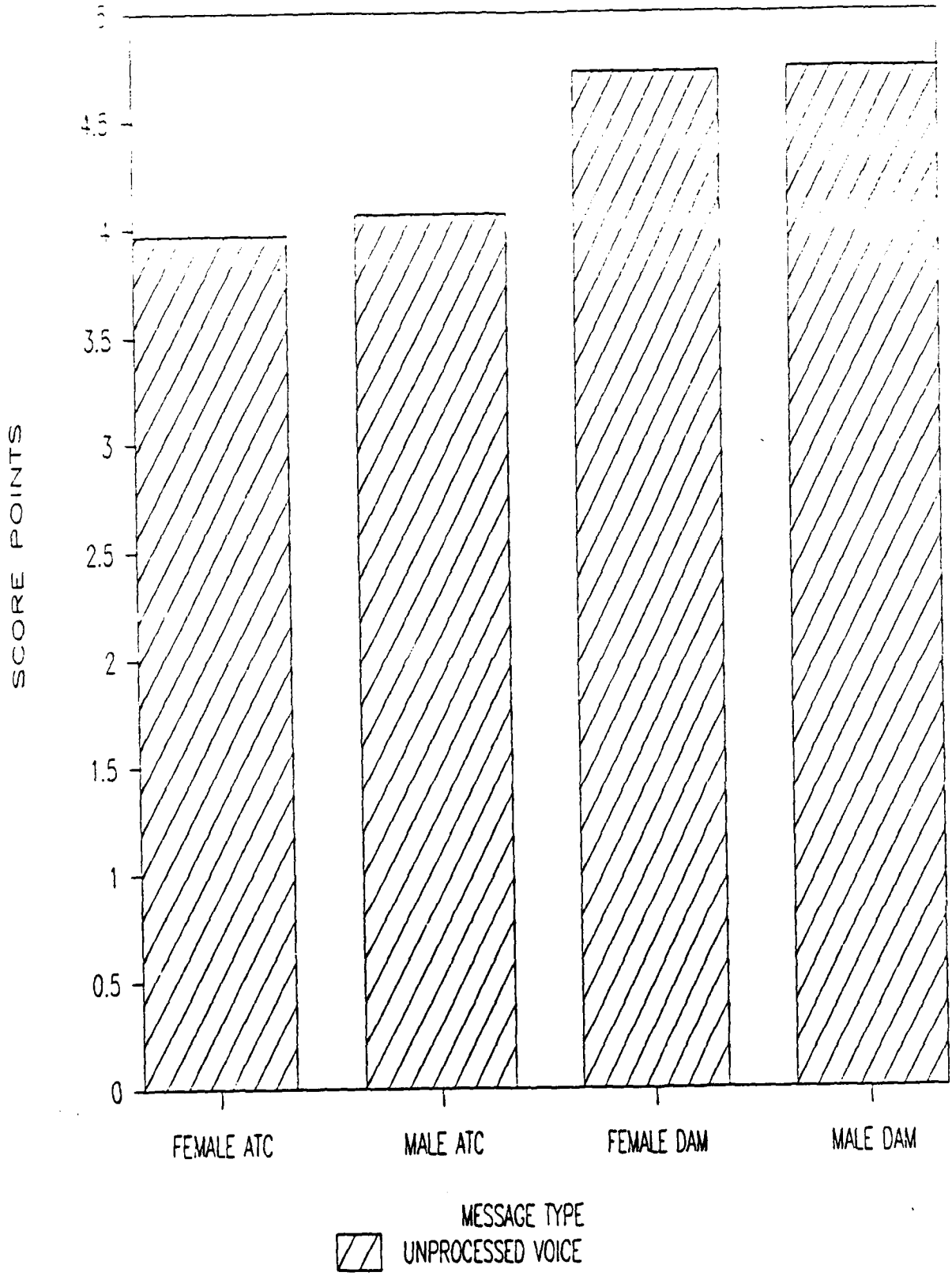

FIGURE 10. INTELLIGIBILITY SCORES (UNPROCESSED)

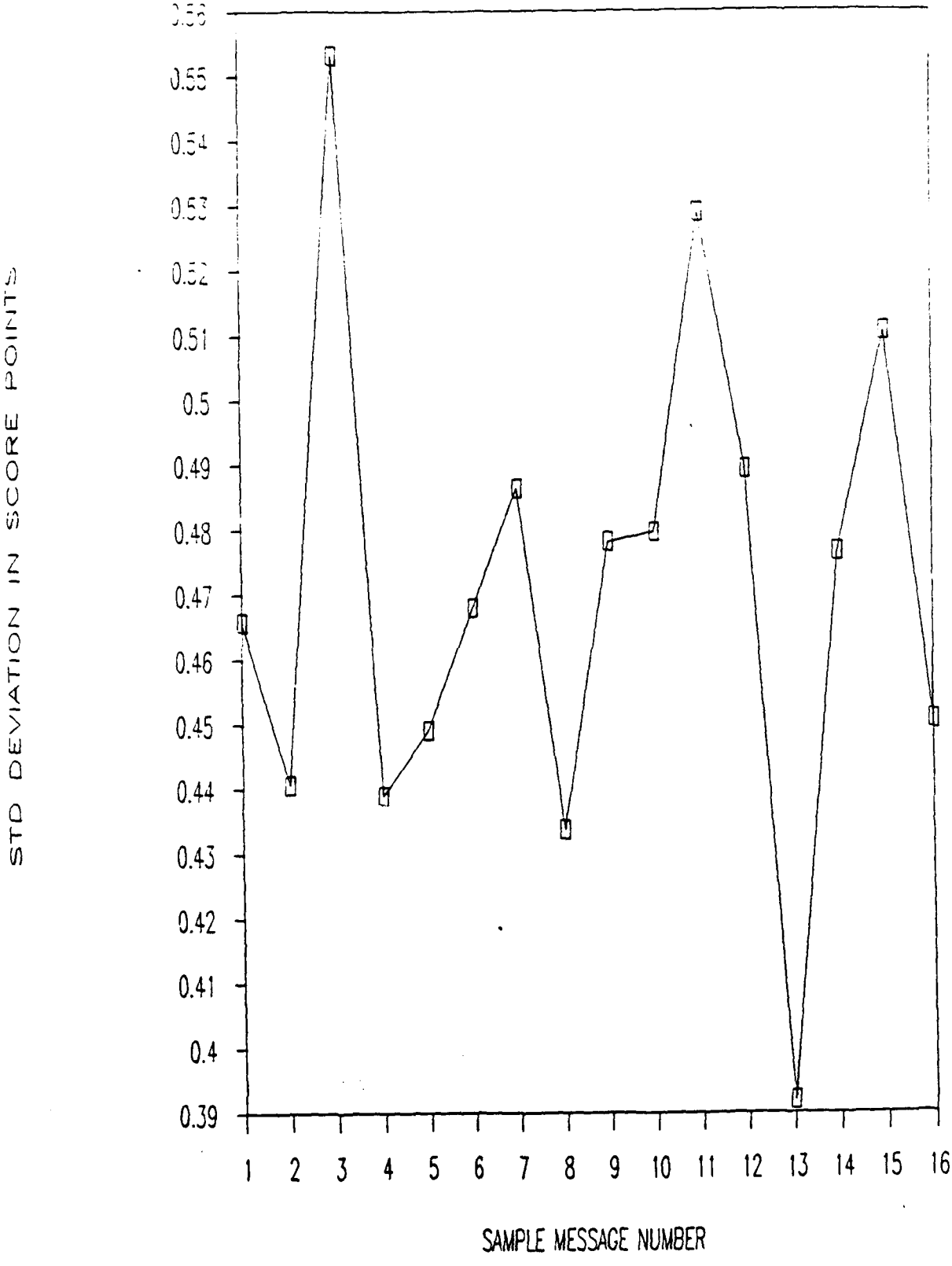

FIGURE 11. STANDARD DEVIATION OF INTELLIGIBILITY SCORES PER MESSAGE TYPE

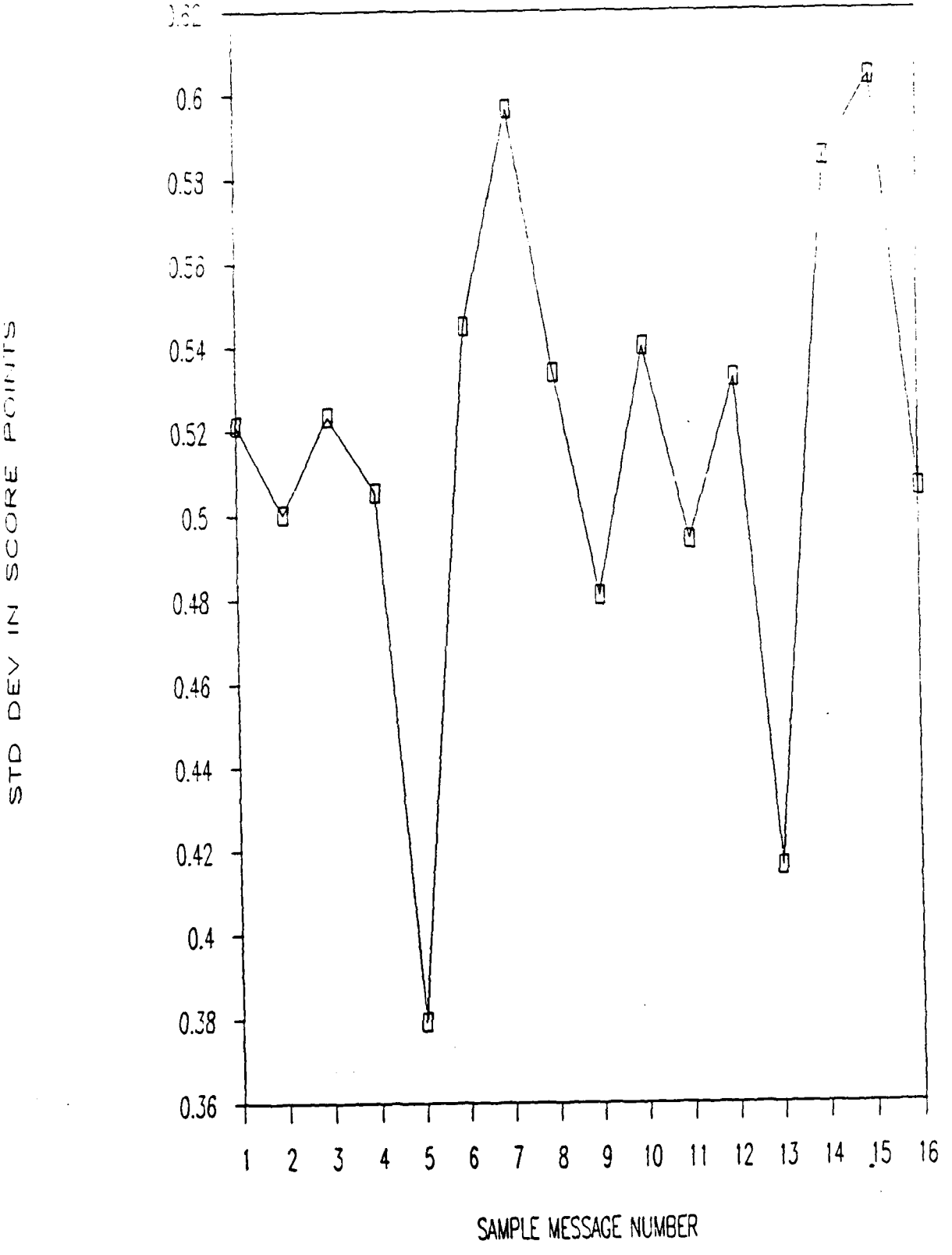

FIGURE 12. STANDARD DEVIATION OF ACCEPABILITY SCORES PER MESSAGE TYPE

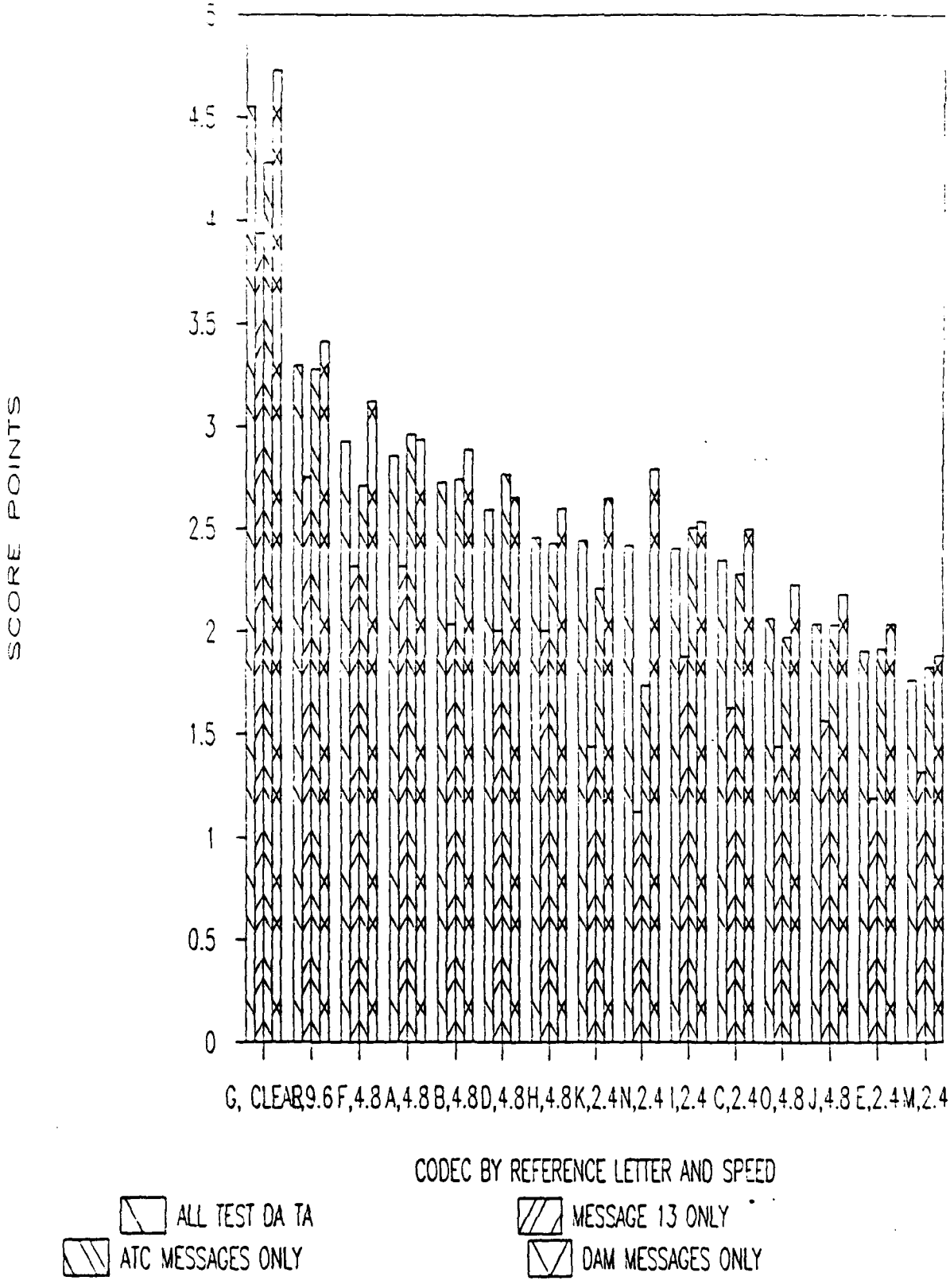

FIGURE 13. INTELLIGIBILITY SCORES VS. MESSAGE TYPE

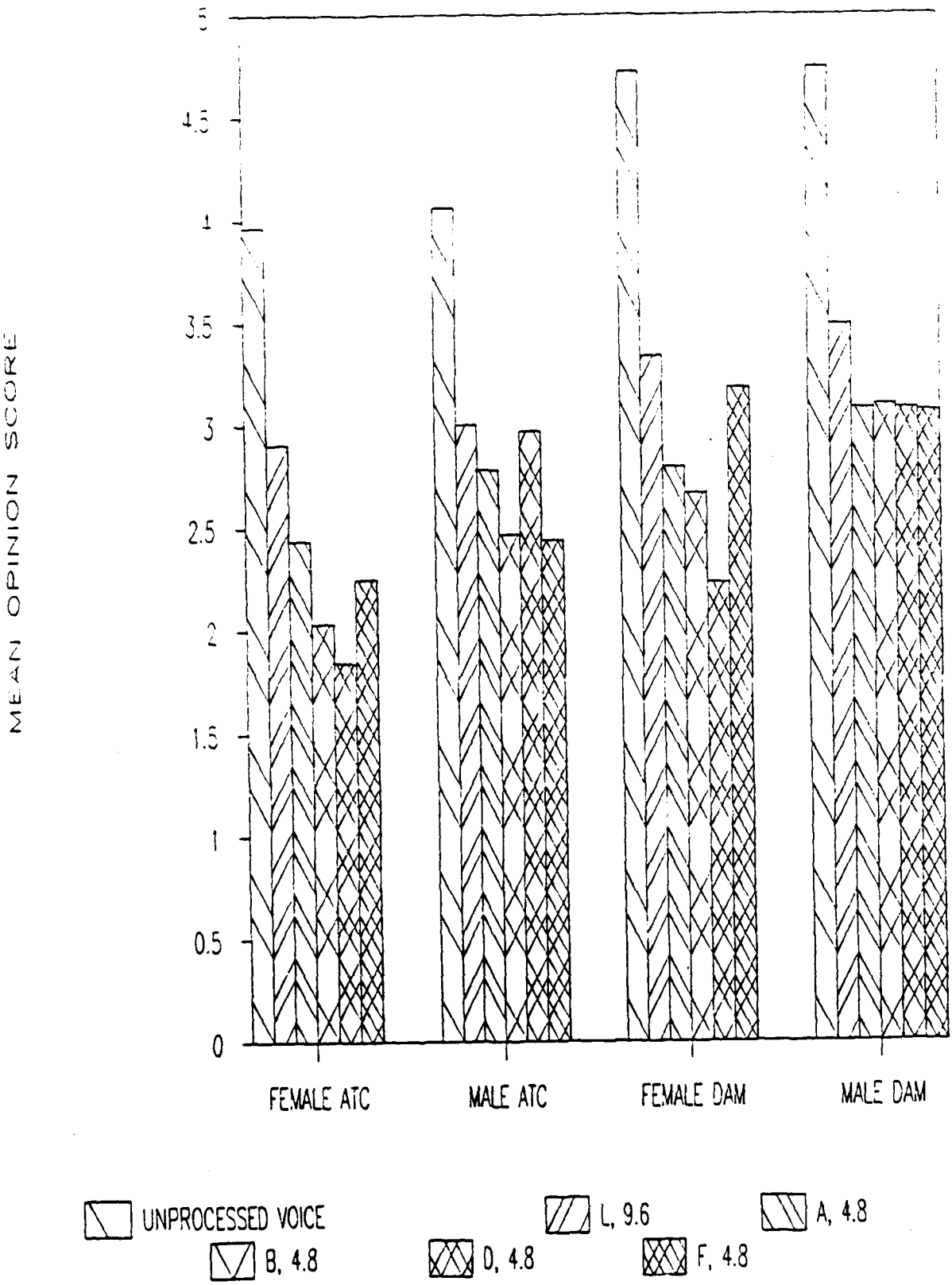

FIGURE 14. INTELLIGIBILITY SCORES FOR VARIOUS MESSAGE TYPES (SHEET 1 OF 3)

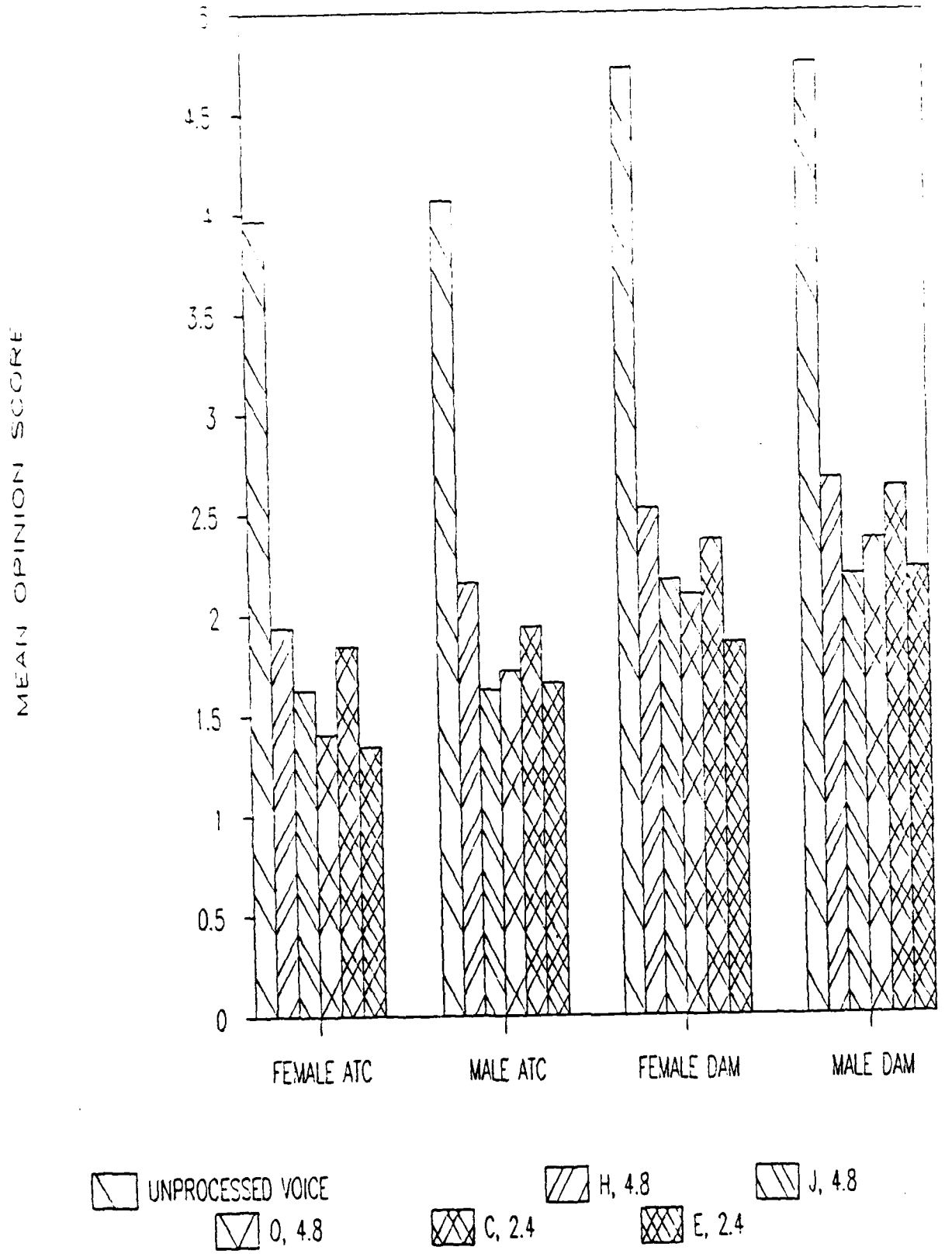

FIGURE 14. INTELLIGIBILITY SCORES FOR VARIOUS MESSAGE TYPES (SHEET 2 OF 3)

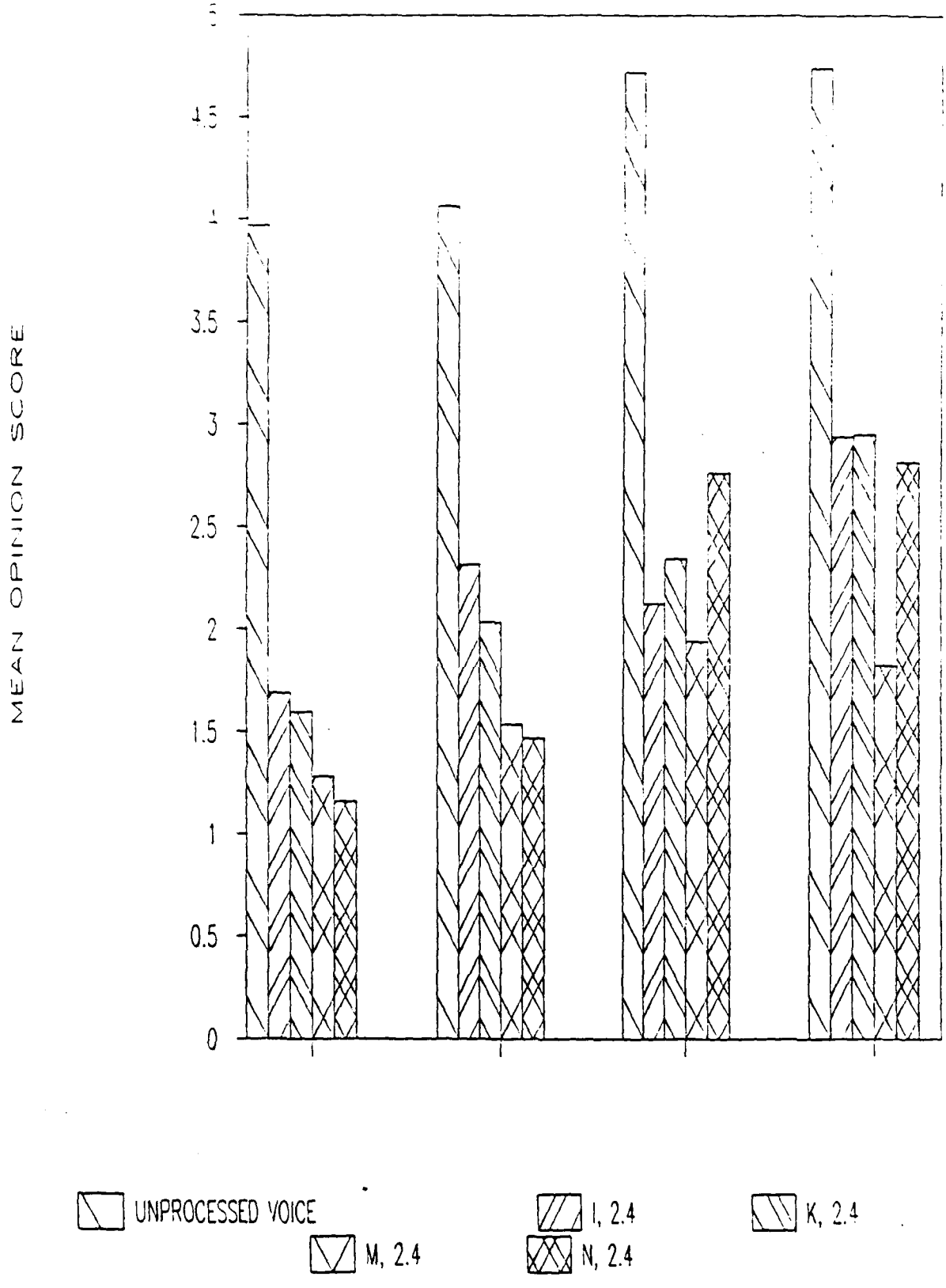

FIGURE 14. INTELLIGIBILITY SCORES FOR VARIOUS MESSAGE TYPES (SHEET 3 OF 3)

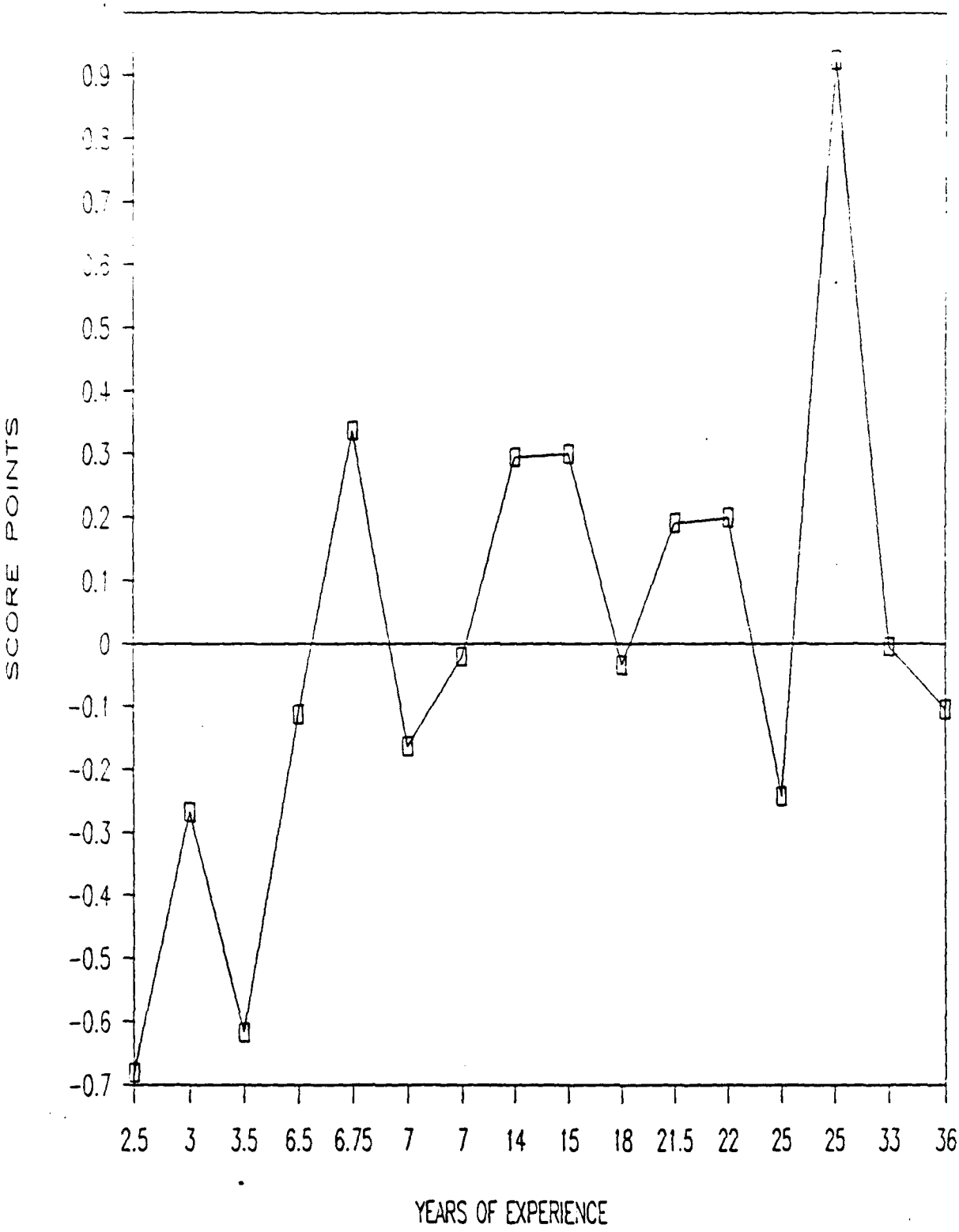

FIGURE 15. DEVIATION OF INTELLIGIBILITY SCORES BY EXPERIENCE

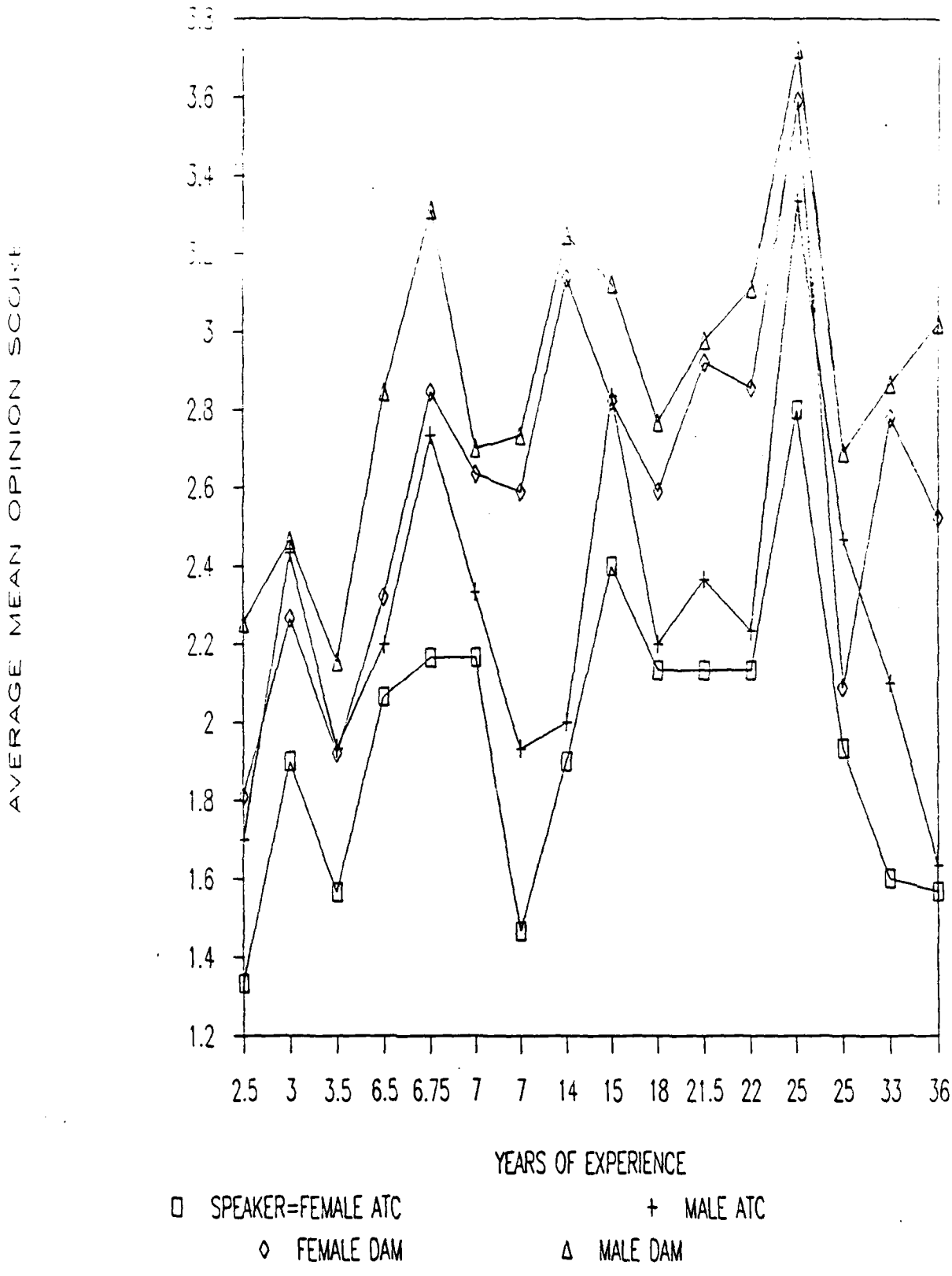

FIGURE 16. INTELLIGIBILITY SCORES BY EXPERIENCE

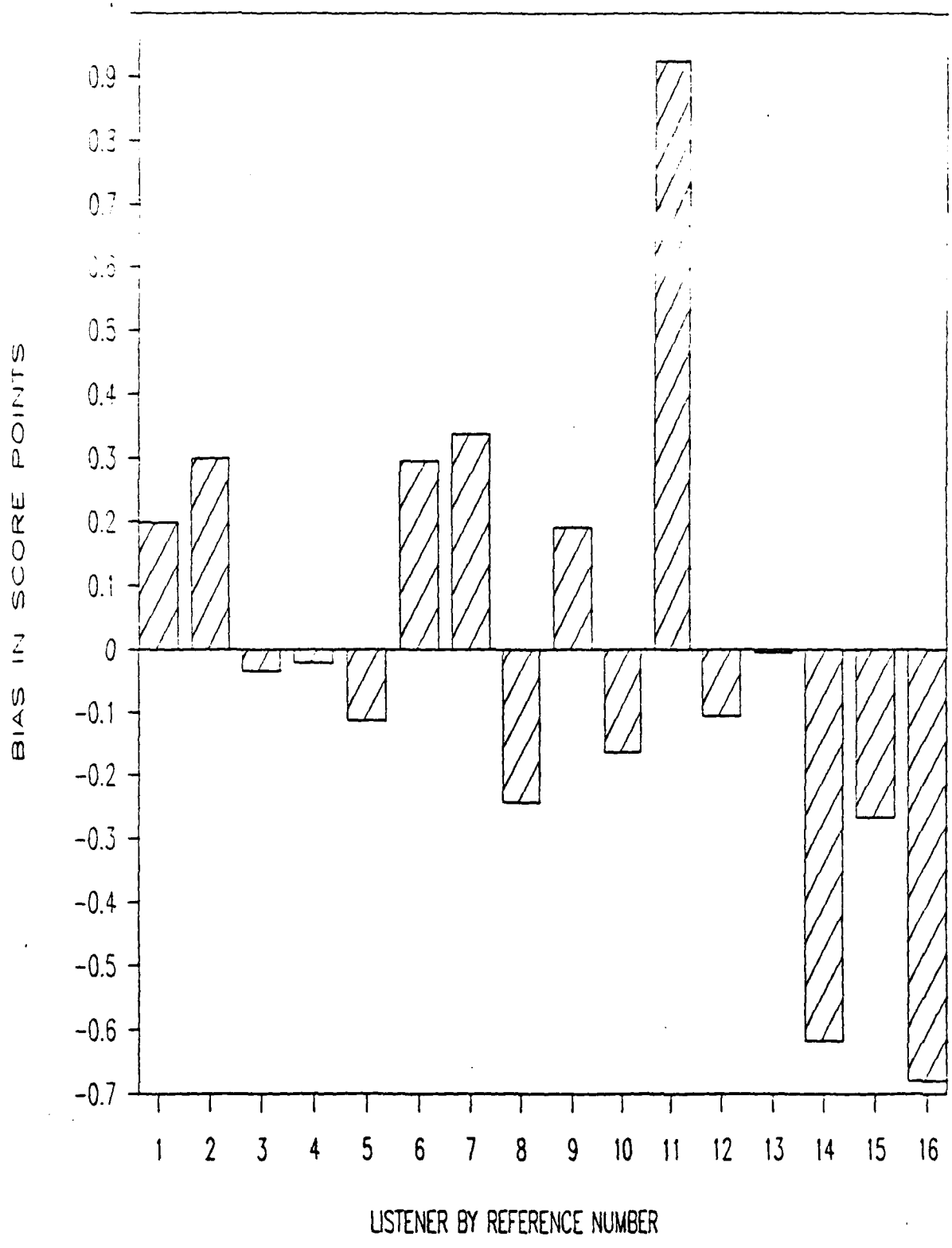

FIGURE 17. AVERAGE BIAS IN INTELLIGIBILITY SCORES

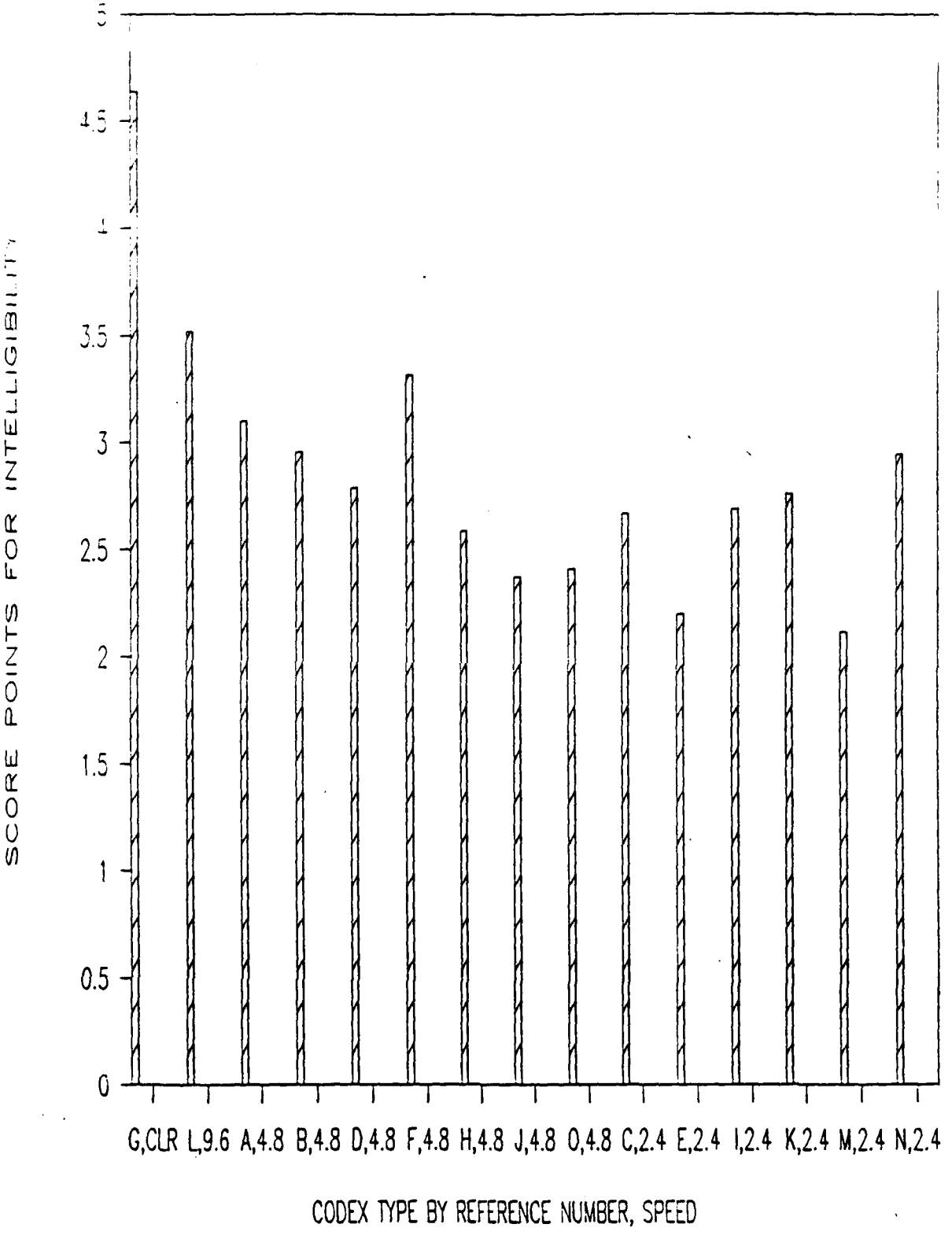

FIGURE 18. AVERAGE OF DAM INTELLIGIBILITY SCORES

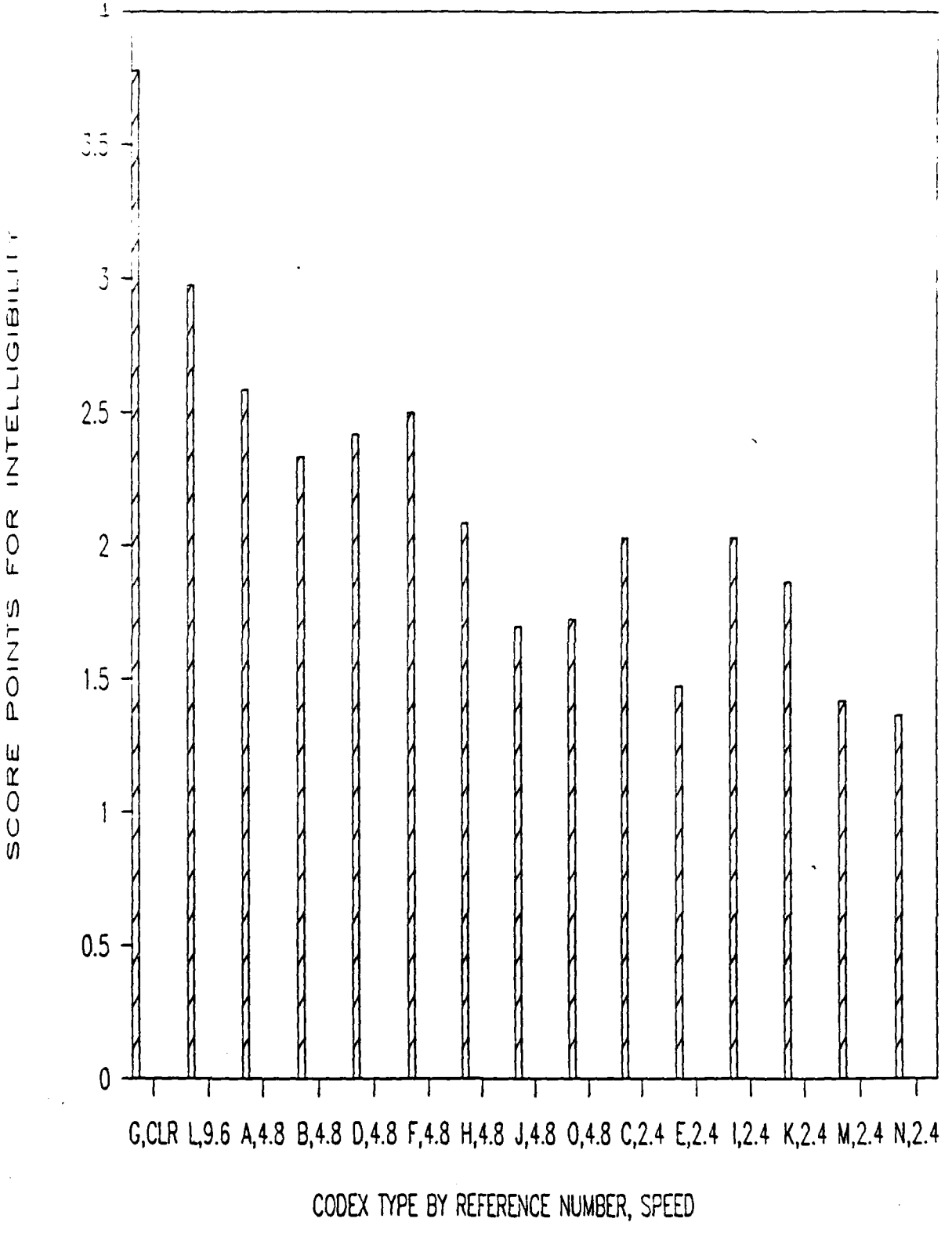

FIGURE 19. AVERAGE OF ATC INTELLIGIBILITY SCORES

APPENDIX A

SUBJECTIVE LISTENING TEST

FAA CODEC SUBJECTIVE LISTENING EVALUATION

for

SATELLITE LOW RATE VOICE DEMONSTRATION AND EVALUATION PROGRAM

PROCEDURE

You will be asked to listen to number of digitally processed audio samples through a set of headphones. This evaluation will consist of two parts. Each part will be divided up into fifteen (15) groups (part 1 will consist of groups 1 - 15 and part 2 of groups 16 - 30). Each group will consist of eight (8) samples each. Finally, each sample will contain either a set of three sentences, or Air Traffic Control (ATC) dialogue. Each group will be arranged according to the following sample sequence:

Sample #	Speaker	Material		Duration
1	FEMALE 1	3 SENTENCES		10 SEC
2	MALE 1	3 SENTENCES		10 SEC
3	FEMALE 2	3 SENTENCES		10 SEC
4	MALE ATC	DIALOGUE		20 SEC
5	FEMALE ATC	DIALOGUE		20 SEC
6	MALE 2	3 SENTENCES		10 SEC
7	FEMALE 3	3 SENTENCES		10 SEC
8	MALE 3	3 SENTENCES		10 SEC
			TOTAL	100 SEC

Each of the two parts will last approximately 40 minutes. There will be a 15 minute intermission after part 1.

Please listen to each complete sample of digitally processed audio, then indicate your opinion of the intelligibility and overall acceptability of sound on the evaluation forms provided to you. There will be a period of silence after each sample for your opinion score. These opinion scores should be evaluated based on the following five-point scale:

5 - EXCELLENT
4 - GOOD
3 - FAIR
2 - POOR
1 - BAD

Thank you for your cooperation!

SUBJECTIVE LISTENING TEST MATERIAL FOR PART 1 (GROUPS 1 - 15)

SAMPLE #	SPEAKER	MATERIAL
1	FEMALE (VW) P/O DAM List 6A2	1)These shoes were black and brown. 2)They are too loud in church. 3)The rabbits and dogs drowned.
2	MALE (CH) P/O DAM List 4A	1)The girl lost the foot race. 2)Card games are fun to play. 3)Happy hour is over.
3	FEMALE (KS) P/O DAM List 8A2	1)My razor gives close shaves. 2)The convicts had no hope. 3)I jumped on the new bed.
4	MALE ATC Dialogue	1)Eastern 731, Atlanta 126.77 Good Morning 2)Eastern's flight 101 Atlanta Center 126.77 Good Morning 3)711 Mike Alpha maintain flight levels 240. 4)US Air's 135 Roger contact Washington Center 125.75.
5	FEMALE ATC Dialogue	1)Delta 799 heavy, contact Atlanta Center 126.77. 2)US Air 447 plus 30 miles northeast of Greensboro at one 1000 on the Greensboro altimeter, 3025. 3)United 1199 turn 10 degrees left, intercept J48 on the Southwest side of Montebello. 4)Roger, United 1199 climb and maintain level 350.
6	MALE (RH) P/O DAM List 6A	1)He sprayed our house for bugs. 2)We saw a bad movie. 3)That hose can wash her feet.
7	FEMALE (MP) P/O DAM List 8A	1)Don't throw trash on the street. 2)They want two red apples. 3)Their cooking was not great.
8	MALE (JE) P/O DAM List 3A	1)Those boxes were not full. 2)All the boys have cold feet. 3)That frog jumped through the weeds.

SUBJECTIVE LISTENING TEST MATERIAL FOR PART 1 (GROUPS 16 - 30)

SAMPLE #	SPEAKER	MATERIAL
1	FEMALE (VW) P/O DAM List 6A2	1)I suggest you leave now. 2)Music can calm the nerves. 3)They sure do take long walks.
2	MALE (CH) P/O DAM List 4A	1)They sat in the cool park. 2)Tom left home in disgust. 3)We watched the new program.
3	FEMALE (KS) P/O DAM List 8A2	1)Sue was fast on her feet. 2)That blue copy was hers. 3)Floods destroyed your attic.
4	MALE ATC Dialogue	1)Westwind 111 hotel november contact Atlanta Center now on 126.77. 2)10 echo golf Washington Center Roger 29 and a half for 310 and uh are you direct to Pulasky or uh Knoxville. 3)Eastern's 119 contact Atlanta 126.77 Good Morning. 4)Delta's 495 Roger. 5)Piedmont's 962 contact Washington Center 133.02 Good Morning.
5	FEMALE ATC Dialogue	1)Delta 95 heavy contact Atlanta Center 126.77. 2)United 1021 Atlanta Center 119(er).57. 3)Power 98 your traffic off now at 11 o'clock and about 12 miles northwest bound out of 330 climbing. 4)Interstate 2114 heavy Washington Center Roger. 5)Lear 442 november echo traffic 12 0'clock 5 miles eastbound of 330, I'll have lower for you momentarily. I'm going to need a good rate of descent for you.
6	MALE (RH) P/O DAM List 6A	1)That goose layed an odd egg. 2)That quiz was much to hard. 3)Those are pudgy old men.

SUBJECTIVE LISTENING TEST MATERIAL FOR PART 1 (GROUPS 16 - 30) (Cont.)

SAMPLE #	SPEAKER	MATERIAL
7	FEMALE (MP) P/O DAM List 8A	1)Invest your money now. 2)Take all the chalk with you. 3)This man was knocked out cold..
8	MALE (JE) P/O DAM List 3A	1)She saved about eight cents. 2)His clothes have some false cuffs. 3)They enjoy loud concerts.

PART 1. Group/Sample Codec Sequence Matrix

	SAMPLE							
	1	2	3	4	5	6	7	8
GROUP								
1 -	A	B	C	D	E	F	G	H
2 -	I	J	K	L	M	N	O	C
3 -	M	F	H	A	L	K	J	O
4 -	G	E	N	B	D	I	C	M
5 -	B	K	O	F	A	J	L	D
6 -	E	G	I	H	N	C	A	F
7 -	K	M	L	O	I	B	D	G
8 -	H	N	E	J	J	O	B	K
9 -	N	A	F	C	G	H	I	E
10 -	D	L	M	N	H	A	E	L
11 -	C	O	B	G	K	D	M	J
12 -	F	I	D	K	O	G	H	B
13 -	J	C	A	M	F	E	N	I
14 -	L	D	G	E	C	M	K	N
15 -	O	H	J	I	B	L	F	A

PART 2. Group/Sample Codec Sequence Matrix

	SAMPLE							
	1	2	3	4	5	6	7	8
GROUP								
16 -	I	M	D	A	J	O	C	G
17 -	E	F	L	B	N	K	H	H
18 -	A	K	B	E	C	M	N	O
19 -	D	J	I	L	G	F	E	A
20 -	O	B	K	M	D	H	L	N
21 -	F	C	G	J	I	B	I	E
22 -	N	O	C	G	A	J	D	K
23 -	H	L	M	F	O	A	G	B
24 -	C	E	F	N	H	D	K	L
25 -	M	I	J	I	L	G	J	D
26 -	B	H	N	O	F	E	M	C
27 -	K	A	A	K	M	I	O	F
28 -	G	D	H	C	E	N	B	J
29 -	L	G	O	H	B	C	F	M
30 -	J	N	E	D	K	L	A	I

SUBJECTIVE LISTENING EVALUATION FORM
FOR
NEW YORK OCEANIC AIR ROUTE TRAFFIC CONTROL CENTER
AUGUST 4, 1988

NAME: _____

TIME: _____

COMMENTS, CRITICISMS, & SUGGESTIONS:

PART 1
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 1 - 4

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
1 (1)	FEMALE 1										
1 (2)	MALE 1										
1 (3)	FEMALE 2										
1 (4)	ATC MALE										
1 (5)	ATC FEMALE										
1 (6)	MALE 2										
1 (7)	FEMALE 3										
1 (8)	MALE 3										
2 (1)	FEMALE 1										
2 (2)	MALE 1										
2 (3)	FEMALE 2										
2 (4)	ATC MALE										
2 (5)	ATC FEMALE										
2 (6)	MALE 2										
2 (7)	FEMALE 3										
2 (8)	MALE 3										
3 (1)	FEMALE 1										
3 (2)	MALE 1										
3 (3)	FEMALE 2										
3 (4)	ATC MALE										
3 (5)	ATC FEMALE										
3 (6)	MALE 2										
3 (7)	FEMALE 3										
3 (8)	MALE 3										
4 (1)	FEMALE 1										
4 (2)	MALE 1										
4 (3)	FEMALE 2										
4 (4)	ATC MALE										
4 (5)	ATC FEMALE										
4 (6)	MALE 2										
4 (7)	FEMALE 3										
4 (8)	MALE 3										

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PART 1
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 5 - 8

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
5 (1)	FEMALE 1										
5 (2)	MALE 1										
5 (3)	FEMALE 2										
5 (4)	ATC MALE										
5 (5)	ATC FEMALE										
5 (6)	MALE 2										
5 (7)	FEMALE 3										
5 (8)	MALE 3										
6 (1)	FEMALE 1										
6 (2)	MALE 1										
6 (3)	FEMALE 2										
6 (4)	ATC MALE										
6 (5)	ATC FEMALE										
6 (6)	MALE 2										
6 (7)	FEMALE 3										
6 (8)	MALE 3										
7 (1)	FEMALE 1										
7 (2)	MALE 1										
7 (3)	FEMALE 2										
7 (4)	ATC MALE										
7 (5)	ATC FEMALE										
7 (6)	MALE 2										
7 (7)	FEMALE 3										
7 (8)	MALE 3										
8 (1)	FEMALE 1										
8 (2)	MALE 1										
8 (3)	FEMALE 2										
8 (4)	ATC MALE										
8 (5)	ATC FEMALE										
8 (6)	MALE 2										
8 (7)	FEMALE 3										
8 (8)	MALE 3										

PART 1
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 9 - 12

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
9 (1)	FEMALE 1										
9 (2)	MALE 1										
9 (3)	FEMALE 2										
9 (4)	ATC MALE										
9 (5)	ATC FEMALE										
9 (6)	MALE 2										
9 (7)	FEMALE 3										
9 (8)	MALE 3										
10 (1)	FEMALE 1										
10 (2)	MALE 1										
10 (3)	FEMALE 2										
10 (4)	ATC MALE										
10 (5)	ATC FEMALE										
10 (6)	MALE 2										
10 (7)	FEMALE 3										
10 (8)	MALE 3										
11 (1)	FEMALE 1										
11 (2)	MALE 1										
11 (3)	FEMALE 2										
11 (4)	ATC MALE										
11 (5)	ATC FEMALE										
11 (6)	MALE 2										
11 (7)	FEMALE 3										
11 (8)	MALE 3										
12 (1)	FEMALE 1										
12 (2)	MALE 1										
12 (3)	FEMALE 2										
12 (4)	ATC MALE										
12 (5)	ATC FEMALE										
12 (6)	MALE 2										
12 (7)	FEMALE 3										
12 (8)	MALE 3										

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PART 1
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 13 - 15

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
13 (1)	FEMALE 1										
13 (2)	MALE 1										
13 (3)	FEMALE 2										
13 (4)	ATC MALE										
13 (5)	ATC FEMALE										
13 (6)	MALE 2										
13 (7)	FEMALE 3										
13 (8)	MALE 3										
14 (1)	FEMALE 1										
14 (2)	MALE 1										
14 (3)	FEMALE 2										
14 (4)	ATC MALE										
14 (5)	ATC FEMALE										
14 (6)	MALE 2										
14 (7)	FEMALE 3										
14 (8)	MALE 3										
15 (1)	FEMALE 1										
15 (2)	MALE 1										
15 (3)	FEMALE 2										
15 (4)	ATC MALE										
15 (5)	ATC FEMALE										
15 (6)	MALE 2										
15 (7)	FEMALE 3										
15 (8)	MALE 3										

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PART 2
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 16 - 19

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
16 (1)	FEMALE 1										
16 (2)	MALE 1										
16 (3)	FEMALE 2										
16 (4)	ATC MALE										
16 (5)	ATC FEMALE										
16 (6)	MALE 2										
16 (7)	FEMALE 3										
16 (8)	MALE 3										
17 (1)	FEMALE 1										
17 (2)	MALE 1										
17 (3)	FEMALE 2										
17 (4)	ATC MALE										
17 (5)	ATC FEMALE										
17 (6)	MALE 2										
17 (7)	FEMALE 3										
17 (8)	MALE 3										
18 (1)	FEMALE 1										
18 (2)	MALE 1										
18 (3)	FEMALE 2										
18 (4)	ATC MALE										
18 (5)	ATC FEMALE										
18 (6)	MALE 2										
18 (7)	FEMALE 3										
18 (8)	MALE 3										
19 (1)	FEMALE 1										
19 (2)	MALE 1										
19 (3)	FEMALE 2										
19 (4)	ATC MALE										
19 (5)	ATC FEMALE										
19 (6)	MALE 2										
19 (7)	FEMALE 3										
19 (8)	MALE 3										

PART 2
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 20 - 23

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
20 (1)	FEMALE 1										
20 (2)	MALE 1										
20 (3)	FEMALE 2										
20 (4)	ATC MALE										
20 (5)	ATC FEMALE										
20 (6)	MALE 2										
20 (7)	FEMALE 3										
20 (8)	MALE 3										
21 (1)	FEMALE 1										
21 (2)	MALE 1										
21 (3)	FEMALE 2										
21 (4)	ATC MALE										
21 (5)	ATC FEMALE										
21 (6)	MALE 2										
21 (7)	FEMALE 3										
21 (8)	MALE 3										
22 (1)	FEMALE 1										
22 (2)	MALE 1										
22 (3)	FEMALE 2										
22 (4)	ATC MALE										
22 (5)	ATC FEMALE										
22 (6)	MALE 2										
22 (7)	FEMALE 3										
22 (8)	MALE 3										
23 (1)	FEMALE 1										
23 (2)	MALE 1										
23 (3)	FEMALE 2										
23 (4)	ATC MALE										
23 (5)	ATC FEMALE										
23 (6)	MALE 2										
23 (7)	FEMALE 3										
23 (8)	MALE 3										

PART 2
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 24 - 27

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
24 (1)	FEMALE 1										
24 (2)	MALE 1										
24 (3)	FEMALE 2										
24 (4)	ATC MALE										
24 (5)	ATC FEMALE										
24 (6)	MALE 2										
24 (7)	FEMALE 3										
24 (8)	MALE 3										
25 (1)	FEMALE 1										
25 (2)	MALE 1										
25 (3)	FEMALE 2										
25 (4)	ATC MALE										
25 (5)	ATC FEMALE										
25 (6)	MALE 2										
25 (7)	FEMALE 3										
25 (8)	MALE 3										
26 (1)	FEMALE 1										
26 (2)	MALE 1										
26 (3)	FEMALE 2										
26 (4)	ATC MALE										
26 (5)	ATC FEMALE										
26 (6)	MALE 2										
26 (7)	FEMALE 3										
26 (8)	MALE 3										
27 (1)	FEMALE 1										
27 (2)	MALE 1										
27 (3)	FEMALE 2										
27 (4)	ATC MALE										
27 (5)	ATC FEMALE										
27 (6)	MALE 2										
27 (7)	FEMALE 3										
27 (8)	MALE 3										

PART 2
SUBJECTIVE LISTENING EVALUATION FORM
FOR GROUPS #: 28 - 30

TEST SEQUENCE		INTELLIGIBILITY					ACCEPTABILITY				
GROUP (SAMPLE)	SPEAKER	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD	5 EXC.	4 GOOD	3 FAIR	2 POOR	1 BAD
28 (1)	FEMALE 1										
28 (2)	MALE 1										
28 (3)	FEMALE 2										
28 (4)	ATC MALE										
28 (5)	ATC FEMALE										
28 (6)	MALE 2										
28 (7)	FEMALE 3										
28 (8)	MALE 3										
29 (1)	FEMALE 1										
29 (2)	MALE 1										
29 (3)	FEMALE 2										
29 (4)	ATC MALE										
29 (5)	ATC FEMALE										
29 (6)	MALE 2										
29 (7)	FEMALE 3										
29 (8)	MALE 3										
30 (1)	FEMALE 1										
30 (2)	MALE 1										
30 (3)	FEMALE 2										
30 (4)	ATC MALE										
30 (5)	ATC FEMALE										
30 (6)	MALE 2										
30 (7)	FEMALE 3										
30 (8)	MALE 3										

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