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A study concerning homophonic entries in the internal lexicon

Erwin R. Wendorff
Lehigh University

A STUDY CONCERNING HOMOPHONIC ENTRIES IN THE INTERNAL LEXICON

by
Erwin R. Wendorff

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Professor in Charge

Chairman of Department

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TABLE OF CONTENTS

LIST OF TABLES

A STUDY OF HOMOPHONIC ENTRIES IN THE INTERNAL LEXICON

ABSTRACT

This experiment was designed around a discrimination task concerning the view that recognition of words involves consulting the internal lexicon. The problem here was to distinguish between English and nonsense words previously recorded on tape. The subject pressed the YES-KEY (English) if he assumed the stimulus word to be English, or NO-KEY (nonsense) if he assumed the stimulus word to be nonsense. As can be expected the response times were much faster for English words than nonsense words, faster also for English words of higher frequency than lower frequency and seemingly faster for homophones than non-homophones. A method is discussed for studying the influence of homophonic entries in relation to human word recognition and it was required that subjects decided whether various strings of letters were English words or not, when presented in immediate succession. Since it is assumed that word recognition requires consulting the internal lexicon, this finding would support the view that accessing a word in lexical memory excites storage locations of some other semantically related words, therefore facilitating their later retrieval. The results of the experiment support a retrieval model involving a certain dependence between successive decisions about whether each of the heard strings is English or nonsense. Presented here is the measuring of reaction time (RT) of the lexical decision as a function of the words

meaning, familiarity, mean word frequency, etc., etc. Words of higher frequency are recognized faster because earlier lexical entry takes place to be compared against stimulus information. Also homophones are recognized sooner than non-homophones because by comparison they have more lexical entries available against stimulus information. To explain the results, it is proposed herewith that word frequency would affect the order of examining stored words in long-term memory and that consequently more replicas of homophones than non-homophones are being stored in long-term memory.

INTRODUCTION

The present study is a further exploration of some of the hypotheses put forth by Rubenstein and his colleagues (Rubenstein, Garfield and Millikan, 1970; Rubenstein, Lewis, and Rubenstein, 1971).

These investigators found that all things being equal, homographs (words which have different meanings but are spelled and pronounced the same i.e., $\underline{\text{yard}}_1$ - enclosure, $\underline{\text{yard}}_2$ - measure) are recognized more quickly than non-homographs for example, desk. The homographs which show this effect were shown to have two characteristics:

1. They were unsystematic with regard to their meaning relationship, and
2. Both meanings were roughly of the same probability or at least the disparity between their probabilities of occurrence was not very great.

Let us consider this first characteristic, the unsystematic nature of their meaning relationship. One could hardly predict the meaning of yard$_2$ from a knowledge of the meaning of yard$_1$. Consider on the other hand the members of the homograph set hammer, the noun meaning 'a kind of tool' and the verb meaning 'to use a hammer'. There are many homograph sets like hammer, one member of which is a noun with the meaning 'a kind of tool' and the other member a verb with the meaning 'to make use of that tool'.

Thus words like hammer, plow, bomb, nail, glue, etc. are considered to be systematic homographs. Rubenstein et al. found these words to behave like non-homographs.

The second characteristic of homographs which were found to have faster recognition times than non-homographs was that both members of the homograph set were roughly equiprobably. Thus the effect was found with homographs like bulb, with the probabilities .63 and .37 for its meanings 'electric light' and 'part of a plant' respectively. But not with fork since its meanings 'eating utensil' and 'division into branches' occur with very unequal probabilities .95 and .05 respectively.

The experimental task employed by Rubenstein et al. involved the discrimination of English and nonsense words. A word was presented visually on the C.R.T. of a computer and the subject was to press a "Yes" key if the word was English, and a "No" key if the word was nonsense. The words were equally divided between these two categories. The period intervening between the presentation of words was 2.5 seconds.

The present study involved the same recognition task that is having the subject decide whether a word is English or nonsense. However the presentation is auditory. This procedure permits the testing not only of homographs but also of homophones, that is words which sound the same but have different spellings and, of course, different meanings, for example, son versus sun, beer versus bier and so forth.

The present study employed 238 words of which 118 were nonsense words. (Appendix K: List of words used in Experiment). Table I shows the classes of words under test in the present experiment. The following hypotheses will be investigated in the present study:

1. The recognition time for English words is less than the recognition time for nonsense words.
2. The recognition time for English words of higher frequency of occurrence is less than the recognition time of English words of lower frequency.
3. The recognition time for homophones is less than the recognition time for non-homonyms.
4. The recognition time for equiprobable homophones is less than the recognition time for unequiprobable homophones.
5. The recognition time for homographs is less than the recognition time for non-homonyms.
6. The recognition time for unsystematic homographs is less than the recognition time for systematic homographs.
7. The recognition time for present tense verb forms is less than the recognition time for past tense verb forms.

8. The recognition time for phonologically legal nonsense words is less than the recognition time for phonologically illegal nonsense words.

METHOD

SUBJECTS. The subjects were employees of Western Electric Company all of whom were college graduates or had some college training. A total of 40 subjects were tested. 20 of these who had scored 90 percent or higher correct in the experiment were selected as the final subject pool. (Appendix A: List of Participants in Experiment). It is the data of these subjects that are analyzed in this study.

WORD STIMULI. The words were all one syllable (4-7 letters) in length. The present and past verb forms, however, were all preceded by they. The frequency of occurrence of the English words was taken from the Lorge Magazine Count as published in the Teachers Wordbook of 30,000 words by E. L. Thorndike and I. Lorge, N.Y., 1944. The low frequency category consisted of words with a frequency of 30-150 occurrences per 4,500,000 words, while the high frequency category consisted of words with a frequency of occurrence of 300-1500 occurrences per 4,500,000 words.

Nonsense words, which matched the English stimuli in length, were of two varieties: phonologically legal nonsense words, that is, words which contained no clusters of phonemes not found in English. These words sounded very much like English words except

for the last phoneme. For instance, drilk which was English up to the last phoneme compared to drilled, or trub which differs from an English word like truss only with regard to the last phoneme. So phonologically legal nonsense words could very well be English except for the historical accident of the English vocabulary. The phonologically illegal nonsense words on the other hand contained combinations of phonemes in the final position which do not occur in English, for example, framk /m/ followed by /k/ simply does not occur at the end of any English word. Cravb similarily contains a cluster /v/ follows by /b/ which does not occur finally in English.

Each subject heard all 238 stimulus words. There were four different orders of presentation of these words prepared and 20 subjects heard each of these lists. In order to prevent the bunching up of words belonging to a particular class in any list each list was made up of nine cycles such that a particular class was represented by the same number of words in each of these cycles. (Instructions to the subjects are given in Appendix B, the List of practice words in Appendix C.).

MATERIALS. Interfacing a peripheral device with a computer involved both hardware and software. (Appendix D: List of Test Equipment to Conduct Experiment and Appendix J: FORTRAN Program). The input/output design made both considerations possible to accomplish. Hardware interface was accomplished simply by inserting printed-circuit interface-cards in easily accessible

input/output slots in the computer and connecting the device cable. (Appendix E: List of Plug-In Interface for Computer Use). The "Hewlett-Packard" 2116 B computer as used in this experiment provided a unique channel identification. It has a 1.6 microsecond memory cycle time with an expandable memory to 32K, and 16 I/O slots in the main frame for device interfacing. The high-speed 2116 B computer memory provided direct memory access (DMA) channels and an extended arithmetic unit. This multiprogramming capability allowed the running of foreground programs in real-time concurrently with background programs. The program was written in Fortran IV. To measure and store the time elapsed from the stimulus sound to the pressing of the key a voice operated electronic relay was built and interfaced with the HP-computer. (Appendix F: Schematic of Voice Operated Relay and Appendix G: Parts List of the Voice Operated Relay). The material selected as test stimuli consisting of 120 English words which were randomly distributed among 118 nonsense words were recorded 4 seconds apart on magnetic polyester recording tape to be played back on a "SONY" TC-630 tape recorder. (Appendix H: Block Diagram of Equipment and Appendix I: Conceptual Scheme of Experiment).

Overall interfacing was accomplished with the help of a Teletype ASR 35 and an "AB DICK" Printer Video Jet 9600. (Appendix L: Program Print-Out-Sample). In order to obtain the average adjusted response time in milliseconds the tape recorded word lengths (Durations) were measured with a "Tectronic" Type 564 B Storage Oscilloscope

with auto-erase and a Type 3A3 dual trace differential amplifier which was used and set to a 0.1 sec./cm. sweep time.

The actual physical arrangement of the experiment was documented with (4) photographs. (Appendix M: Photo 1 - Equipment Arrangement, Photo 2 - Voice Operated Electronic Relay, Photo 3 - Subject Being Tested, Photo 4 - Instructor and Subject During Test).

RESULTS

The results of the experiment are given in Tables I and II. The tables also include data on the duration of the stimuli. The durations were measured because it was observed that although all the stimuli, both nonsense and English, were monosyllabic (except for the addition of they in the verb forms), they nevertheless differed considerably in duration. The column marked response time (RT) in the tables was obtained by taking the interval between the presentation of the word and the key press. The average adjusted response time (AdjRT), which is the most interesting metric, was obtained by subtracting the duration of the word from this unadjusted reaction time.

Results and Discussion

1. English vs. Nonsense. The clearest effect obtained was that the time to respond correctly that a word was English was less than the time to respond correctly that a word was nonsense. The AdjRT (English) 332 msec. was just a little more than half the AdjRT (nonsense) which came to 648 msec. This

resembles the result obtained by Rubenstein & his co-workers in their visual experiments. The explanation offered by Rubenstein for the longer RT for nonsense is that the decision that a word is nonsense does not involve finding the stimulus word in the internal lexicon as in the case of English but searching the internal lexicon more or less exhaustively to make sure that the stimulus is not listed.

2. Word Frequency. The well-established hypothesis that the greater the frequency of occurrence of a word the more readily it is perceived was well corroborated in the present study. There were five comparisons in which the greater frequency condition was represented by words in the 300-1500 range and the lesser frequency was represented by words in the 30-150 range. In all five comparisons the AdjRT (greater frequency) < AdjRT (lesser frequency):

HEH 319	<	HEL 367
HUH 331	<	HUL 342
GSH 316	<	GSL 320
GUH 291	<	GUL 356
UH 316	<	UL 398

3. Phonological Illegality. Comparison of phonologically legal (pronounceable) nonsense with phonologically illegal (less pronounceable) nonsense yielded an unexpected result. The AdjRT (legal) = 639 msec. < AdjRT (illegal) = 666 msec. This difference was found to be statistically significant.

This result is inconsistant with the finding of Rubenstein, Lewis & Rubenstein (Phonemic Recording 1971) who found that in a visual presentation, phonologically illegal nonsense words were identified as nonsense more quickly than the legal nonsense words.

They explained their finding by hypothesizing that the nonsense character of the phonologically illegal words was discovered in the quantization stage, i.e., in the process of mapping the visual stimulus onto letters and recoding the letter into phonemes. The nonsense character of the phonologically legal words could only be discovered by exhaustive search of the internal lexicon. The inconsistency of the finding of the present experiment with their finding could well be due to the difference in the mode of presentation. In Rubenstein, Lewis & Rubenstein experiment the stimulus was displayed unti' the subject responded. In the present study, the stimulus was presented auditorily. When the subject thought he detected an illegality, he could only reexamine the stimulus by going to his echo memory of the word. It may well be that this is a slower process than reexamining a visual display. The fact that no errors at all were made in the responses to phonologically illegal nonsense indicates both that we are very sensitive to violations of phonological rules and that the echo memory for short segments is very reliable.

4. Homonym Effects. According to the model proposed by Rubenstein and his co-workers, homonyms (whether homographs or homophones) should have faster response times than nonhomonyms. The reasoning is that it is easier to find one of the two or more representations of the homonym in the internal lexicon (if it does not matter which one is found) than to find the single representation of the non-homonym. It was further reasoned that this homonym effect would occur only if the different members of the homonym set were of relatively equal frequency so that they would both be present in the same search period. And finally, it seemed reasonable to suppose that homonym sets like hammer in which one of the meanings was systematically derived from the other would have a single representation in the internal lexicon.

Since we had only 9 words in each of the classes involved, and since the homonym effect is small relative, say, to the word frequency effect it was hardly to be expected that the present study would yield clear cut results. The results, shown in Table III, are indeed far from clear cut. Only one hypothesis, the one regarding the effect of homography, tends in the right direction in both the high and low frequency case.

One factor that may have obscured the tests seemed to be the inaccuracy of the word frequency controls. Accordingly we obtained familiarity judgment on the English stimuli: a group of 20 other subjects was asked to judge their familiarity with the words (the relative frequency with which they wrote, read, spoke or heard them)

on an 8-point scale. The mean judged familiarity of each stimulus class was then calculated (Table II). The logarithm of AdjRTs plotted against the mean familiarity can be reasonably fitted by a straight line with a slope showing a change of approximately 5 msec in RT to .1 of familiarity. If RT is compensated for differences in familiarity one of the reversals shown in Table III is eliminated. See Table IV. Two reversals remain both in the low word frequency category:

$$RT(HEL) > RT(HUL) \text{ and } RT(GUL) > RT(GSL).$$

The results have not been tested for statistical significance since the small number of words tested could not provide a convincing demonstration in view of the great amount of word variance that is to be expected in such experiments.

This work is to be viewed as a pilot study which, fortunately, suggests that there may be some merit in further investigation of these hypotheses with much larger sets of stimuli.

APPENDIX A

List of Participants in Experiment

1. K. Criswell	(1)	B.S. 1965	Penn State
2. G. Loughery	(2)	B.S. 1960	Penn State
3. D. Walls	(3)	B.S. 1956	Penn State
4. A. Cook	(4)	B.S. 1942	Penn State
5. J. Trondsen	(1)	B.S. 1965, M.S. 1970	University of M.D.
6. D. Lockart	(2)	B.S. 1944	Yale
7. T. Sawyer	(1)	B.S. 1953	Annapolis
8. J. Gilbert	(2)	M.S. 1969	Drexel University
9. R. Noble	(3)	B.S. 1970	G. Washington Univ.
10. F. Naples	(4)	B.S. 1968	Penn State
11. J. Bond	(1)	M.S. 1959	Univ. of Miami
12. D. Gittelman	(3)	M.S. 1953, M.B. 1966	Univ. of Penn.
13. F. Leibold	(1)	B.S. 1953	Penn State
14. B. Davis	(4)	B.S. 1968	Lehigh University
15. W. Rohall	(1)	B.S. 1958	Penn State
16. R. Colesworthy	(3)	B.S. 1972	Albright College
17. G. Anderson	(4)	B.S. 1952	Penn State
18. J. Bestel	(1)	Ph.D. 1971	B'klyn Polytech.
19. F. Doxie	(4)	B.S. 1950	Univ. of Miami
20. C. Zeigler	(4)	B.S. 1966	Villanova

APPENDIX B:

Homophone Experiment
Instructions to the Subjects

This is an experiment designed to give us some understanding of how the words of our language are stored in our memory. This is not a test of your knowledge of English. Your performance will be averaged together with the performances of other persons to give us a general picture.

You will hear a number of words. Some are English and some are nonsense. Your task is to decide for each word as quickly as possible whether it is English or not. If it is English you will press the key marked "Yes" (English). If it is not English, you will press the key marked "No" (Nonsense). You will have to listen very closely. Each word will be heard only once. There will be no repetitions. Most of the nonsense words will sound like some English word except for the last consonant. For example, one nonsense word might be tib which might sound like tip, or tin if you weren't listening closely.

You will have to respond quickly since there will only be a 4 second pause between words. And you must respond to each word before the next word begins. So try to respond as fast as you can while trying to be as accurate as you can.

Be sure to respond to each word even when you think you are guessing. The English words used in this experiment include both common and relatively uncommon words but they are all words that you know. No names of persons or places are used.

One more thing. While most of the expressions you will hear are single syllable words, there will be some expressions consisting of they plus some single syllable word. These are to be considered English only if the word following they is English. If the word following they is nonsense, for example, they sorp, you should identify the phrase as nonsense. Both words of the phrase would have to be English for the phrase to be correctly identified as English.

You will now hear some practice words so that you can become familiar with the task. But first do you have any questions?

APPENDIX C

Homophone Experiment

Practice 25 Eng. 25 Nons. Mixed

1. sock
2. curfe
3. kipe
4. leck
5. veen
6. they cost
7. call
8. corm
9. flane
10. west
11. they porg
12. quick
13. fope
14. fame
15. they felt
16. lack
17. crant
18. sport
19. sofk
20. they force
21. arm
22. den
23. flib
24. shime
25. clue
26. hand
27. quis
28. inch
29. sound
30. maze
31. pim
32. nose
33. sog
34. nest
35. they solze
36. sult
37. chin
38. forn
39. drine
40. court
41. toass
42. frist
43. pank
44. they packed
45. pite
46. fox
47. pince
48. fling
49. they curfed
50. clash

APPENDIX D

TEST EQUIPMENT NECESSARY TO CONDUCT THE EXPERIMENT:

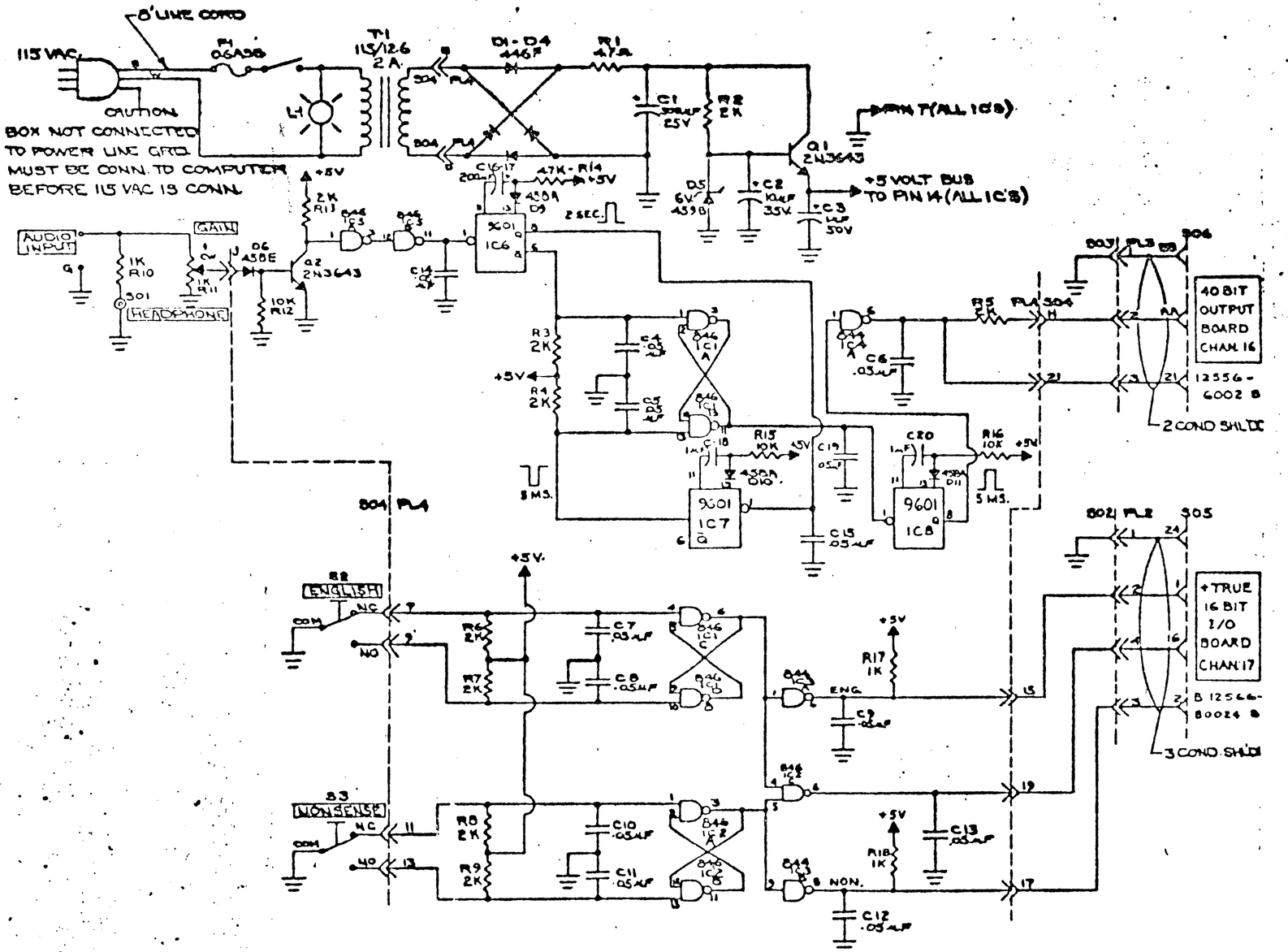
1.	"Sony" Stereo Tape Recorder TC-630	$ 445.00
2.	Voice Operated Electronic Relay, W.E. Co.	415.00
3.	Headphones HP-1, 300 Ω	35.00
4.	"Hewlett Packard" 2116B Computer	24,000.00
5.	"Hewlett Packard" 2748A Tape Reader	1,500.00
6.	"Hewlett Packard" 2753A Tape Punch	3,700.00
7.	"Hewlett Packard" Teletype ASR 35	4,500.00
8.	"AB Dick" Printer Videojet 9600	10,000.00
9.	Magnetic Recording Tape 1800 ft. Polyester (L.P.)	5.00
10.	One "HP" 40 Bit Board, Output, 12556-6002B, Chanel 16	252.50
11.	One "HP" +True 16 Bit Board, Answer, Ass'y. B 12566-80024, Chanel 17	252.50
	Total:	$45,105.00

APPENDIX E

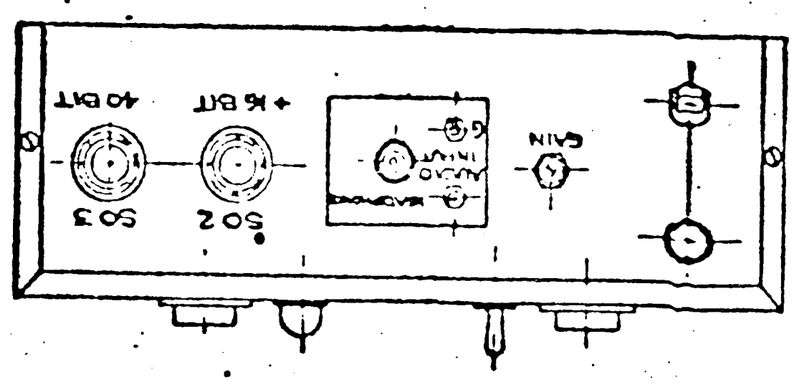
PLUG-IN INTERFACE FOR HP COMPUTER MODEL 2116B

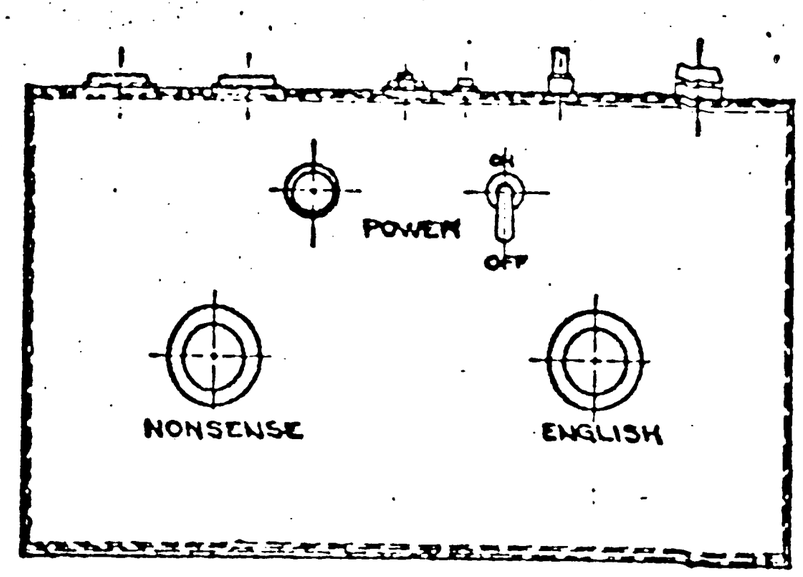
Channel	I/O	Serial No.
10	Time Base Generator	02116-6119
11	Line Printer/+True/In/Out	12566-80024
12	Reader/+8 Bit/Duplex Reg.	12597-8001
13	Punch/Tape Punch	02116-6245
14	Teletype/Buffered TTY Reg.	12531-6001
16	40 Bit Board (Output)	12556-6002B
17	+True 16 (Answer)	B 12566-80024 B

APPENDIX F: Schematic of Voice-Operated Relay

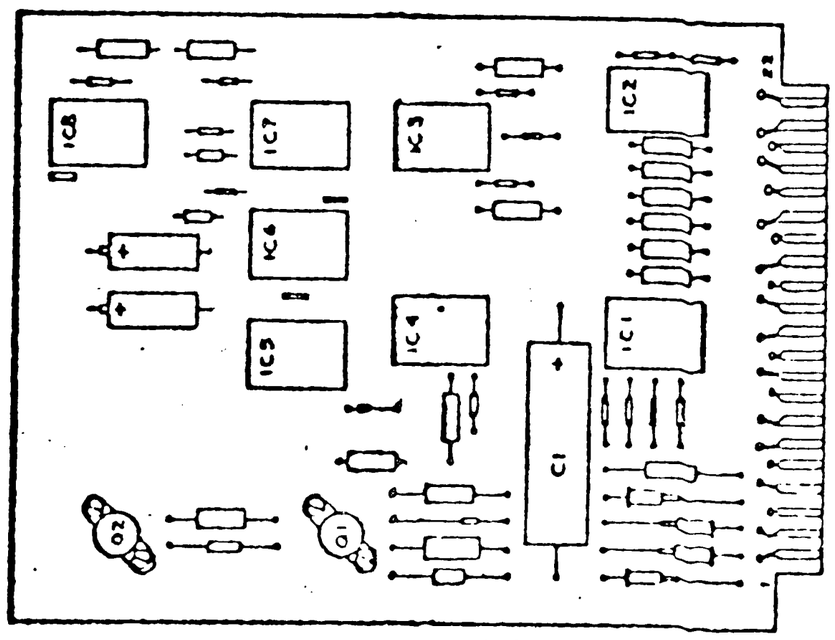


APPENDIX F: Schematic of Voice-Operated Relay





CONSOLE
SCALE: 1/8



CIRCUIT BOARD
P4

PIN [illegible] - INT. COMMON
PIN 21 - $\overline{\text{START}}$ TO 40 BIT OUTPUT BOARD
PIN 19 - $\overline{\text{SIGN BIT}}$ TO + TRUE 16 BIT I/O BOARD
PIN 17 - $\overline{\text{NON.}}$ TO + TRUE 16 BIT I/O BD. (BIT 1)
PIN 15 - $\overline{\text{ENG.}}$ TO + TRUE 16 BIT I/O BD. (BIT Ø)
PIN 13 - NON. (N.O.)
PIN 11 - NON. (N.C.)
PIN J - AUDIO INPUT
PIN 9 - ENG. (N.O.)
PIN H - +12.6 V.D.C.
PIN 7 - ENG. (N.C.)
PIN D - 12.6 VAC
PIN B - 12.6 VAC
PIN 1 - INT. COMMON

APPENDIX G:

WORD DISCRIMINATION EQPT.

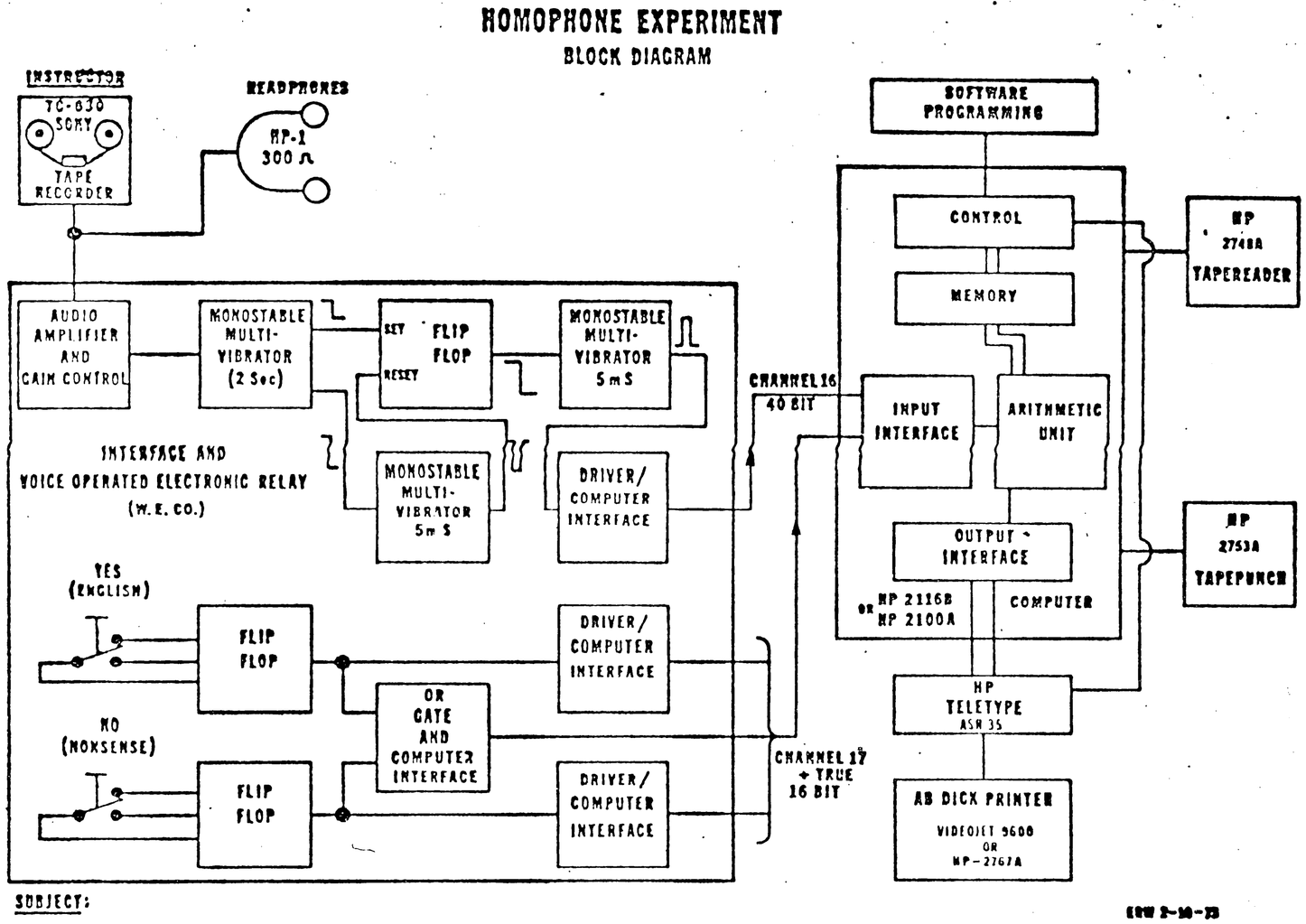
Parts List

Item	# Req'd.	Description
1	1	Box 12" x 7" x 4"
2	1	Board (P4) Vero
3	2	Switch (S2, S3) BZ-R88-A2
4	1	Fuseholder
5	1	Fuse (F1) 0.6A S.B.
6	1	Transformer (T1) 12.6V @ 2A
7	2	Actuators (S2 & S3)
8	1	Receptacle (S04)
9	1	Switch (S1)
10	4	Diodes (D1-D4, 446F)
11	1	Diode (D5, 459B)
12	1	Diode (D6)
13	3	Diodes (D9-11, 458A)
14	1	Capacitor C1 500 μF 25V
15	1	Capacitor C2 10 μF 35V
16	4	Capacitor C3, 18, 20 1 μF 50V

	17	13	Capacitor C4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 19 .047 µF 100V
	18	1	Resistor R1 4.7 Ω 1/2W
	19	9	Resistor R2, 3, 4, 5, 6, 7, 8, 9, 13 2K Ω 1/2W
	20	2	Transistors Q1 & Q2 2N3643
	21	2	Transistor Sockets Grayhill 22-11
	22	3	2 IN. NAND'S Mot. 846P (IC 1, 2, & 5)
	23	2	Dual Power Gates Mot. 844P (IC 3 & 4)
	24	8	DIP Sockets Augat 314-AG1A
	25	1	Plug (PL2) 91-MC4M
	26	1	Socket (SO2) 91-PC4F
	27	2	Receptacles (SO 5 & 6) CCC Type K600 -13PC-24
	28	1	Pilot Lamo Ass'y (LI) 115 VAC
	29	1	Plug (PL3) 91-MC3M
	30	1	Socket (SO3) 91-PC3F

31	1	Pot 2 Watt 1K R11
32	1	Pin Jack, Red
33	1	Pin Jack, Black
34	1	Phone Jack (So-1)
35	2	Capacitors C16 & 17 100 F (6V)
36	3	Resistor R 10, 17, 18 1K 1/2W
37	3	Resistor R 12, 15, 16 10K 1/2W
38	3	Integrated Circuits IC 6, 7, 8 9601
39	1	Resistor R 14 47K 1/2W

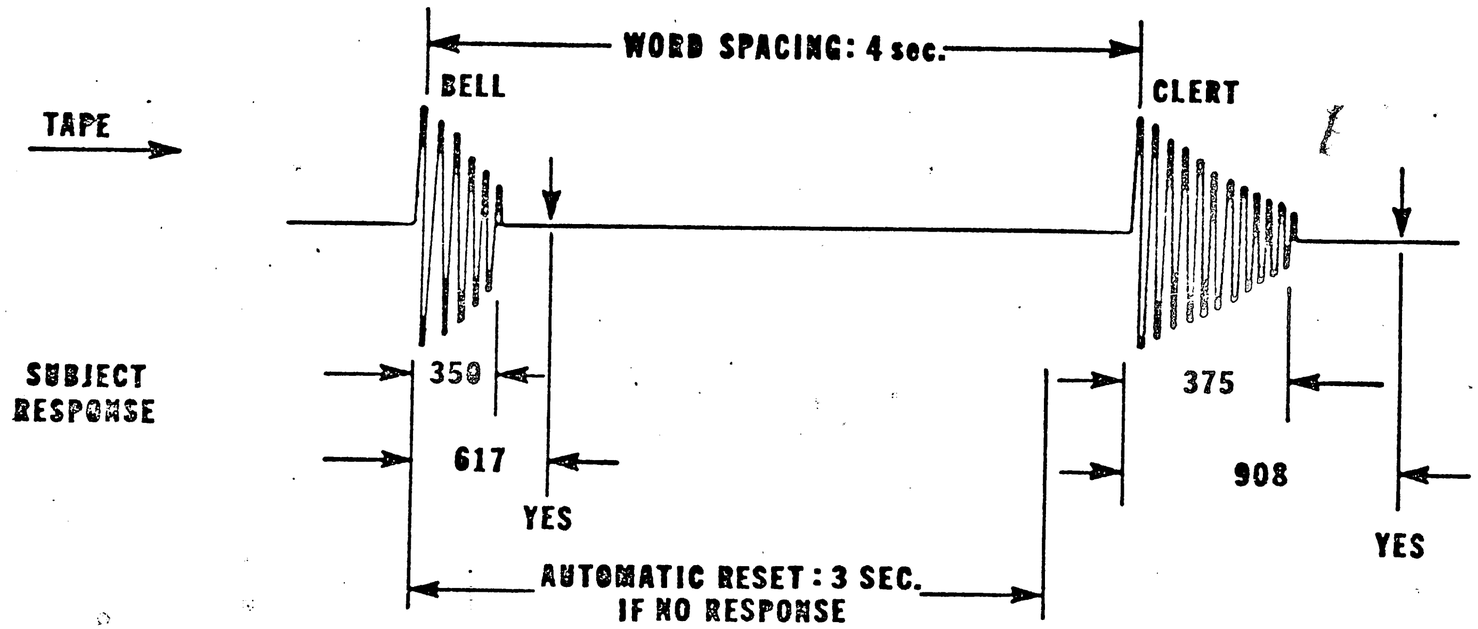
APPENDIX H: Block Diagram of Equipment



APPENDIX I

CONCEPTUAL SCHEME OF HOMOPHONE EXPERIMENT

NUMBER	WORD	CYCLE	TYPE	SUBJECT RESPONSE	TEST WORD	RESPONSE COMPARISON	R/T MS	DURATION MS
40	BELL	2	HUH	E	E	C	617	350
41	CLERT	2	L	N	N	C	908	375



≅ 5 MILLI SEC. TOTAL DELAY

APPENDIX J: Fortran Program


```
0001  FTN,A
0002  C                    E. R. WENDORFF
0003  C
0004  C                    VOPI DISCRIMINATOR PROJECT
0005  C
0006  C                    H.N. SCHAPPELL  1/12/73
0007  C
0008  C                    16B = 48 BIT OUTPUT CARD
0009  C                    17B = TRUE I/O CARD 16 BIT
0010  C                    ALL COMPILATION RUN UNDER DOS-M
0011  C
0012  C
0013  C
0014        PROGRAM MAIN
0015        DIMENSION IFILE(240,12),IN(15)
0016        COMMON ITIME(240),IANSW(240),ICLK1
0017        WRITE(1,70)
0018     70 FORMAT(///,"PLEASE INPUT THE LIST NUMBER, (1 TO 41?.")
0019        READ(1,*)LSTNM
0020        WRITE(6,1)LSTNM
0021      1 FORMAT(///,15X,"HOMOPHONE EXPERIMENT (RUBENSTEIN/WENDORFF).",
0022       C///,22X,"PROGRAM FOR LIST ",I1," WORDS")
0023        WRITE(1,2)
0024      2 FORMAT("PLEASE INPUT MONTH, DAY AND YEAR?.")
0025        READ(1,*)IMONT,IDAY,IYEAR
0026        WRITE(1,3)
0027      3 FORMAT(///,"PLEASE INPUT YOUR FIRST TWO INITIALS AND FULL"
0028       C" LAST NAME",/,"?.")
0029        READ(1,4)IN(1),IN(2),IN(3),IN(4),IN(5),IN(6),IN(7),IN(8),
0030       C IN(9),IN(10),IN(11),IN(12),IN(13),IN(14),IN(15)
0031      4 FORMAT(15A2)
0032        DO 5 K=1,240
0033        TTIME(K)=0
0034        IANSW(K)=0
0035      5 CONTINUE
0036        WRITE(1,6)
0037      6 FORMAT(///,"PLEASE TURN TAPERECORDER ON TO START TESTING.",
0038       C//,"ARE YOU READY TO START?.")
0039        READ(1,7)IA
0040      7 FORMAT(A1)
0041        IF(IA=131B)8,9,8
0042      9 CALL CLKST
0043        CALL INPST
0044        DO 18 K=1,240
0045        IF(ITIME(K)=200)17,17,15
0046     15 IF(ITIME(K)=2500)14,17,14
0047     16 IF(IANSW(K)=0)17,14,17
0048     17 IANSW(K)=IANSW(K)*10
0049     14 CONTINUE
0050        INCE=0
0051        INCNO=0
0052        IENG=0
0053        INON=0
0054        INVE=0
0055        INVNO=0
0056        INR=0
0057        IVENG=0
0058        IVNON=0
0059        VENTH=0
0060        VNOTH=0
```

```
0061            VINOT=0.
0062            VIENT=0
0063         20 WRITE(1,18)LSTNM
0064         18 FORMAT(//,'PLEASE PLACE MODE ',I1,' TAPE IN PHOTOREADER.',//,
0065           C'IS THE TAPE READY TO READ?',/)
0066            READ(1,19)IA
0067         19 FORMAT(A1)
0068            IF(IA-139)20,21,20
0069         21 DO 22 K=1,240
0070         22 READ(5,23)IFILE(K,1),IFILE(K,2),IFILE(K,3),IFILE(K,4),
0071           CIFILE(K,5),IFILE(K,6),IFILE(K,7),IFILE(K,8),IFILE(K,9)
0072         23 FORMAT(602,202,I1)
0073            DO 24 K=1,240
0074         24 READ(5,25)IFILE(K,11)
0075         25 FORMAT(A2)
0076            DO 26 K=1,240
0077            IF(IANSW(K)-0)27,32,27
0078         27 IF(IANSW(K)-1)28,33,28
0079         28 IF(IANSW(K)-2)29,36,29
0080         29 IF(IANSW(K)-10)30,39,30
0081         30 IF(IANSW(K)-20)31,42,31
0082         31 STOP1
0083         32 INO=INO+1
0084            IFILE(K,10)=471228
0085            IFILE(K,12)=471228
0086            GO TO 26
0087         33 IENG=IENG+1
0088            IFILE(K,10)=424428
0089            IF(IFILE(K,10)-IFILE(K,11))35,34,35
0090         34 IVENG=IVENG+1
0091            IFILE(K,12)=414028
0092            TIME=ITIME(K)
0093            VENTM=VENTM+TIME
0094            GO TO 26
0095         35 IFILE(K,12)=444028
0096            INCEN=INCEN+1
0097            TIME=ITIME(K)
0098            VIENT=VIENT+TIME
0099            GO TO 26
0100         36 INON=INON+1
0101            IFILE(K,10)=470428
0102            IF(IFILE(K,10)-IFILE(K,11))38,37,38
0103         37 IVNON=IVNON+1
0104            IFILE(K,12)=414028
0105            TIME=ITIME(K)
0106            VNOTM=VNOTM+TIME
0107            GO TO 26
0108         38 IFILE(K,12)=444028
0109            INCNO=INCNO+1
0110            TIME=ITIME(K)
0111            VINOT=VINOT+TIME
0112            GO TO 26
0113         39 INVEN=INVEN+1
0114            IFILE(K,12)=445052
0115            IF(IFILE(K,11)-424408)41,40,41
0116         40 IFILE(K,12)=445038
0117            GO TO 26
0118         41 IFILE(K,12)=445118
0119            GO TO 26
0120         42 INVNO=INVNO+1
```

```
0121          IFILE(K,10)=44516B
0122          IF(IFILE(K,11)-47B-10B)44,43,44
0123       43 IFILE(K,12)=44503B
0124          GO TO 86
0125       44 IFILE(K,12)=44511B
0126       86 CONTINUE
0127          CEN=INCEN
0128          CNO=INCNO
0129          VENG=IVENG
0130          VNON=IVNON
0131          AVGEN=VENTH/VENG
0132          AVGNO=VNOTH/VNON
0133          AVTEN=IVENT/CEN
0134          AVTNO=IVNOT/CNO
0135          PRCT1=(VENG/110.)*(100.)
0136          PRCT2=(VNON/121.)*(100.)
0137          PRCT3=((VENG+VNON)/231.)*(100.)
0138          PRCT4=(CEN/110.)*(100.)
0139          PRCT5=(CNO/121.)*(100.)
0140          PRCT6=((CEN+CNO)/231.)*(100.)
0141          IF(VENTH-0.)78,78,71
0142       71 IF(VENG-0.)82,82,72
0143       72 IF(VNOTH-0.)79,79,73
0144       73 IF(VNON-0.)83,83,74
0145       74 IF(VTENT-0.)80,80,75
0146       75 IF(CEN-0.)84,84,76
0147       76 IF(VINCT-0.)81,81,77
0148       77 IF(CNO-0.)85,85,86
0149       78 AVGEN=0
0150          GO TO 71
0151       79 AVGNO=0
0152          GO TO 73
0153       80 AVTEN=0
0154          GO TO 75
0155       81 AVTNO=0
0156          GO TO 77
0157       82 AVGEN=0
0158          PRCT1=0
0159          PRCT3=0
0160          GO TO 72
0161       83 AVGNO=0
0162          PRCT2=0
0163          PRCT3=0
0164          GO TO 74
0165       84 AVTEN=0
0166          PRCT4=0
0167          PRCT6=0
0168          GO TO 76
0169       85 AVTNO=0
0170          PRCT5=0
0171          PRCT6=0
0172       86 WRITE(6,46)LSTNM,IMONT,IDAY,IYEAR,IN(1),IN(2),IN(3),IN(4),
0173         CIN(5),IN(6),IN(7),IN(8),IN(9),IN(10),IN(11),IN(12),IN(13),
0174         CIN(14),IN(15)
0175       46 FORMAT(///,25X,"RESULTS FROM LIST ",I1,//,1X,"DATE: ",2(I2,1
0176         CH,//,1X,"NAME: ",15A2)
0177          WRITE(6,47)
0178       47 FORMAT(///,1X,"NUMBER",5X,"WORD",6X,"CYCLE",9X,"TYPE",9X,
0179         C"SUBJECT",3X,"TEST",4X,"RESPONSE",4X,"R.T.",/,35X,"RESPONSE"
0180         CPX,"WORD",3X,"COMPARISON")
```

```
0181          DO 48 K=1,240
0182       48 WRITE(6,49)K,IFILE(K,1),IFILE(K,2),IFILE(K,3),IFILE(K,4),
0183         CIFILE(K,5),IFILE(K,6),IFILE(K,7),IFILE(K,8),
0184         CIFILE(K,10),IFILE(K,11),IFILE(K,12),ITIME(K)
0185       49 FORMAT(1X,I3,4X,6A2,4X,I1,4X,2A2,4X,A2,7X,A2,8X,A2,7X,I4)
0186          WRITE(6,50)
0187       50 FORMAT(///,1X,"N:  NONSENSE",/,1X,"E:  ENGLISH",/,1X,"IN: ",
0188         C"INVALID-NONSENSE",/,1X,"IE:--INVALID ENGLISH",/,1X,"NR: ",
0189         C"NO RESPONSE",/,1X,"C:  CORRECT",/,1X,"I:  INCORRECT",/,1X,
0190         C"IE: INVALID CORRECT",/,1X,"II: INVALID INCORRECT",/,1X,
0191         C"ALL TIMES LISTED ARE IN MILLISECONDS")
0192          WRITE(6,51)INR,IENG,INON,INVEN,INVNO
0193       51 FORMAT(///,1X,"TOTAL SUBJECT NO RESPONSE",I4,//,1X,"TOTAL ",
0194         C"SUBJECT ENGLISH RESPONSE",I4,//,1X,"TOTAL SUBJECT NONSENSE",
0195         C" RESPONSE",I4,//,1X,"TOTAL SUBJECT INVALID ENGLISH RESPONSE"
0196         C,I4,//,1X,"TOTAL SUBJECT INVALID NONSENSE RESPONSE",I4)
0197          WRITE(6,100)IVENG,IVNON,INCEN,INCNO,AVGEN
0198      100 FORMAT(///,1X,"TOTAL SUBJECT VALID CORRECT ENGLISH RESPONSE",
0199         CI4,//,1X,"TOTAL SUBJECT VALID CORRECT NONSENSE RESPONSE",I4,
0200         C//,1X,"TOTAL SUBJECT VALID INCORRECT ENGLISH RESPONSE",I4,
0201         C//,1X,"TOTAL SUBJECT VALID INCORRECT NONSENSE RESPONSE",I4,
0202         C//,1X,"AVERAGE TIME FOR VALID CORRECT RESPONSE TO ENGLISH",
0203         C/,1X,"TEST WORDS",F10.2)
0204          WRITE(6,101)AVGNO,AVTEN,AVINO,PRCT1
0205      101 FORMAT(///,1X,"AVERAGE TIME FOR VALID CORRECT RESPONSE TO",
0206         C/,1X,"NONSENSE TEST WORDS",F10.2,//,1X,"AVERAGE TIME FOR VAL"
0207         C" INCORRECT RESPONSE TO",/,1X,"ENGLISH TEST WORDS",F10.2,//,
0208         C1X,"AVERAGE TIME FOR VALID INCORRECT RESPONSE TO",/,1X,"NO"
0209         C"NSENSE TEST WORDS",F10.2,//,1X,"PERCENT VALID CORRECT RES"
0210         C"PONSE TO ENGLISH TEST WORDS",F10.2)
0211          WRITE(6,102)PRCT2,PRCT3,PRCT4,PRCT5,PRCT6
0212      102 FORMAT(///,1X,"PERCENT VALID CORRECT RESPONSE TO NONSENSE"
0213         C" TEST WORDS",F10.2,//,1X,"PERCENT VALID CORRECT RESPONSE "
0214         C"TO TOTAL TEST WORDS",F10.2,//,1X,"PERCENT VALID INCORRECT "
0215         C"RESPONSE TO ENGLISH TEST WORDS",F10.2,//,1X,"PERCENT VALID"
0216         C" INCORRECT RESPONSE TO NONSENSE TEST WORDS",F10.2,//,1X,
0217         C"PERCENT VALID INCORRECT RESPONSE TO TOTAL TEST WORDS",F10.2)
0218          WRITE(1,56)
0219       56 FORMAT(/,"PLEASE TURN PUNCH ON AND PUNCH LEADER ON TAPE.")
0220       57 WRITE(1,58)
0221       58 FORMAT(/,"READY TO PUNCH?←")
0222          READ(1,59)A
0223       59 FORMAT(A1)
0224          IF(10-13)57,60,57
0225       60 DO 61 K=1,240
0226       61 WRITE(4,62)ITIME(K)
0227       62 FORMAT(I4)
0228          DO 63 K=1,240
0229       63 WRITE(4,64)IFILE(K,10)
0230       64 FORMAT(A2)
0231          DO 65 K=1,240
0232       65 WRITE(4,66)IFILE(K,11)
0233       66 FORMAT(A2)
0234          WRITE(4,67)
0235       67 FORMAT(///,1X,"PROGRAM COMPLETE")
0236          END
0237          ENDS
**** LIST END ****
```

PAGE 0002 #01 POINT TIME AND INPUT DATA

```
0001                    *SMA.R.A.L
0003*
0004*
0005*           SUBROUTINE TO CHECK THE TIME AND ANSWER
0006*
0007*
0008*                   W.N. SCHAPPELL  1/12/73
0009*
0010*
0011  00000                     NAM INPST
0012                            ENT INPST
0013                            COM TTIME(240),IANSW(240),ICLK1
0014  00000 00000 TIME          DEF TTIME
0015  00001 000360 ANSWR        DEF IANSW
0016  00002 000000 INPST        NOP
0017  00003 062000              LDA TIME
0018  00004 072052              STA TIMAD
0019  00005 062001              LDA ANSWR
0020  00006 072153              STA ANSAD
0021  00007 062057              LDA =D-240      SET WORD LIMIT COUNTER
0022  00010 072540              STA COUNT
0023  00011 006400              CLB             SET WORD COUNTER
0024  00012 107716              CLC STFLG,C     CLEAR START FLAG
0025  00013 002400  WAIT1       CLA
0026  00014 103404              SFS STFLG       WAS START REQUESTED?
0027  00015 026013              JMP WAIT1       NO, WAIT FOR START
0028  00016 072740              STA ICLK1       YES, START TIMING INPUT
0029  00017 102517  WAIT2       LIA ANSLG       READ ANSWER CARD
0030  00020 012556              AND MASK1
0031  00021 002020              SSA             WAS ANSWER GIVEN?
0032  00022 026040              JMP STORE       YES, STORE ANSWERS
0033  00023 026041              JMP CHECK       NO, CHECK MAX. TIME
0034  00024 012560  STORE       AND MASK2
0035  00025 172053              STA ANSAD,I     STORE ANSWER IN IANSW MAT.
0036  00026 062740              LDA ICLK1
0037  00027 172052              STA TIMAD,I     STORE TIME IN ITIME MAT.
0038  00030 036520  CONT        ISZ TIMAD       INC. ITIME MAT. COUNTER
0039  00031 036053              ISZ ANSAD       INC. IANSW MAT. COUNTER
0040  00032 006004              INB             INCREMENT WORD COUNTER
0041  00033 107716              CLC STFLG,C     CLEAR START FLAG
0042  00034 036540              ISZ COUNT       INC. WORD COMPAIR COUNTER
0043  00035 026013              JMP WAIT1       NEXT WORD
0044  00036 107716  RETN        CLC STFLG,C     CLEAR START FLAG
0045  00037 105720              LDB INPST,I
0046  00040 124000              JMP 0,I         RETURN TO FORTRAN MAIN
0047  00041 062740  CHECK       LDA ICLK1
0048  00042 042560              ADA =B-5679
0049  00043 002021              SSA             IS MAX. TIME UP?
0050  00044 026170              JMP WAIT2       NO, WAIT LONGER
0051  00045 062740              LDA ICLK1       MAX. TIME ELASPED
0052  00046 172052              STA TIMAD,I     STORE MAX. TIME IN ITIME
0053  00047 002400              CLA
0054  00050 172053              STA ANSAD,I     STORE NO RESPONSE IN IANSW
0055  00051 026030              JMP CONT
0056  00016          STFLG EQU 16B        16 BIT OUTPUT CARD
0057  00017          ANSLG EQU 17B        * TRUE I/O 16 BIT CARD
```

```
PAGE 0003 001  POINT TIME AND INPUT DATA


0058  000052 000000  TIME MATRIX COUNTER
0059  000053 000000  IANSW MATRIX COUNTER
0060  000054 000000  POINT NOP
0061  000055 177773  MASK1 OCT 177773
0062  000056 000003  MASK2 OCT 3
      000057 177420
      000060 177414
0063                 END
** NO ERRORS *
```

```
PAGE 0002 #01

0001                      ASMB,R,B,L
0002*
0003* CONTINUATOR SECTION FOR T.R.G.
0004*
0005*                                   H.N. SCHAPPELL 8/8/72
0006*
0007  00000                      NAM TRINT
0008                             ENT TRINT
0009                             COM ITIME(240),IANSW(240),ICLK1
0010  00000 000740C  ICLO1  DEF ICLK1
0011  00010          TRGEN  EQU 10B
0012  00001 000000   TRINT  NOP
0013  00002 136000R         ISZ ICLO1,I   INCRIMENT CLOCK 1 COUNTER
0014  00003 000000          NOP
0015  00004 103110   RETN   CLF TRGEN
0016  00005 126001R         JMP TRINT,I
0017                        END
**  NO ERRORS*
```

APPENDIX K: List of Words Used in Experiment

	List 1	E/N	C/I	Cycle 1	Duration
1.	they tast	N	I	V	760
2.	son-sun	E	C	HEH	300
3.	fank	N	I	L	260
4.	pray-prey	E	C	HEL	240
5.	they thought	E	C	PAST A	500
6.	hint	E	C	GSL	250
7.	quelt	N	I	L	420
8.	they sling	E	C	PRES. B	600
9.	sight-site	E	C	HUH	220
10.	nesp	N	I	L	460
11.	framk	N	I	I	475
12.	clup	N	I	L	150
13.	pork	E	C	UL	220
14.	leask	N	I	L	430
15.	they glite	N	I	VC	490
16.	tear-tier	E	C	HUL	300
17.	maint	N	I	L	550
18.	town	E	C	UH	430
19.	they drive	E	C	PRES. A	530
20.	they breag	N	I	VC	600
21.	crabg	N	I	I	450
22.	scorp	N	I	L	420
23.	crafe	N	I	L	210
24.	dumb	E	C	GUL	325
25.	cook	E	C	GSH	230
26.	block	E	C	GUH	330

Nomenclature:
E = English
N = Nonsense
C = Correct
I = Incorrect
Duration = Actual Word Length in millisec.

	List 1	E/N	C/I	Cycle 2	Duration
27.	they shrank	E	C	PAST A	610
28.	sleem	N	I	L	600
29.	floe-flow	E	C	HUL	300
30.	radsh	N	I	I	610
31.	drawk	N	I	L	400
32.	smalt	N	I	L	600
33.	bell-belle	E	C	HUH	200
34.	prip	N	I	L	250
35.	loaf	E	C	GUL	220
36.	wink	E	C	GSL	340
37.	flamt	N	I	L	390
38.	they stride	E	C	PRES. B	700
39.	heal-heel	E	C	HEL	330
40.	cove	E	C	UL	300
41.	they vauld	N	I	V	700
42.	fuzg	N	I	I	450
43.	loan-lone	E	C	HEH	320
44.	brain	E	C	UH	320
45.	trick	E	C	GSH	250
46.	they cobe	N	I	VC	760
47.	clert	N	I	L	380
48.	kind	E	C	GUH	480
49.	plact	N	I	L	450
50.	they sell	E	C	PRES. A	620
51.	they roke	N	I	VC	580
52.	snate	N	I	L	350

List 1	E/N	C/I	Cycle 3	Duration
53. vial-vile	E	C	HUL	320
54. they ran	E	C	PAST A	550
55. solve	E	C	UL	360
56. kroz	N	I	L	415
57. glazb	N	I	I	485
58. they cobe	N	I	VC	725
59. trene	N	I	L	660
60. wise	E	C	UH	280
61. they spend	E	C	PRES. B	620
62. mife	N	I	L	300
63. they came	E	C	PAST A	500
64. marp	N	I	L	400
65. slay-sleigh	E	C	HEL	270
66. blame	E	C	GSH	420
67. flasp	N	I	L	525
68. they charp	N	I	V	565
69. they canse	N	I	VC	610
70. steal-steel	E	C	HEH	200
71. wesp	N	I	L	360
72. they dig	E	C	PRES. A	570
73. ant-aunt	E	C	HUH	420
74. fleet	E	C	GUL	260
75. plam	N	I	L	420
76. tufk	N	I	I	350
77. they reaz	N	I	VC	725
78. sweat	E	C	GSL	210
79. fall	E	C	GUH	300

	List 1	E/N	C/I	Cycle 4	Duration
80.	round	E	C	UH	520
81.	stune	N	I	L	650
82.	judge	E	C	GSH	300
83.	they told	E	C	PAST B	450
84.	since	E	C	GUH	200
85.	they worg	N	I	VC	650
86.	pawn	E	C	GUL	305
87.	trucp	N	I	I	350
88.	sland	N	I	L	480
89.	hair-hare	E	C	HUH	360
90.	staim	N	I	L	500
91.	firse	N	I	L	435
92.	they found	E	C	PAST B	520
93.	sneap	N	I	L	440
94.	they sting	E	C	PRES. A	525
95.	greel	N	I	L	400
96.	guilt-gilt	E	C	HUL	220
97.	slack	E	C	UL	310
98.	jume	N	I	L	485
99.	they cound	N	I	VC	855
100.	chart	E	C	GSL	230
101.	breach-breech	E	C	HEL	305
102.	cravb	N	I	I	315
103.	weak-week	E	C	HEH	325
104.	stron	N	I	L	675
105.	they samt	N	I	V	855

	List 1	E/N	C/I	Cycle 5	Duration
106.	they slung	E	C	PAST B	555
107.	park	E	C	GUH	300
108.	grovt	N	I	I	520
109.	grast	N	I	L	500
110.	they brought	E	C	PAST B	550
111.	they lefs	N	I	VC	510
112.	flad	N	I	L	360
113.	beer-bier	E	C	HUL	310
114.	peal-peel	E	C	HEL	210
115.	glant	N	I	L	450
116.	they think	E	C	PRES. A	515
117.	shart	N	I	L	500
118.	need-knead	E	C	HUH	405
119.	they mart	N	I	VC	640
120.	lump	E	C	UL	430
121.	wait-weight	E	C	HEH	250
122.	paint	E	C	GSH	300
123.	strig	N	I	L	350
124.	they send	E	C	PRES. B	600
125.	brown	E	C	UH	240
126.	thonb	N	I	I	450
127.	they clask	N	I	V	450
128.	quarp	N	I	L	355
129.	they drove	E	C	PAST A	550
130.	barp	N	I	L	250
131.	plow	E	C	GSL	180
132.	they sailt	N	I	VC	660
133.	rash	E	C	GUL	250
134.	rolt	N	I	L	430
135.	they wrike	N	I	VC	580

	List 1	E/N	C/I	Cycle 6	Duration
136.	duck	E	C	GUL	260
137.	clipe	N	I	L	210
138.	pain-pane	E	C	HUH	260
139.	breep	N	I	L	400
140.	plum-plumb	E	C	HEL	240
141.	they felp	N	I	VC	520
142.	crusp	N	I	L	300
143.	they shrink	E	C	PRES. A	550
144.	slint	N	I	L	400
145.	juice	E	C	UH	420
146.	they blop	N	I	VC	630
147.	jump	E	C	GSH	310
148.	jusk	N	I	L	365
149.	they sold	E	C	PAST A	500
150.	roast	E	C	GSL	280
151.	cresf	N	I	I	400
152.	sail-sale	E	C	REH	350
153.	framp	N	I	L	300
154.	hent	N	I	L	400
155.	rye-wry	E	C	HUL	365
156.	they gend	N	I	V	800
157.	grim	E	C	UL	280
158.	they strode	E	C	PAST B	800
159.	rudk	N	I	I	380
160.	type	E	C	GUH	200
161.	shife	N	I	L	310

	List 1	E/N	C/I	Cycle 7	Duration
162.	hort	N	I	L	425
163.	blow	E	C	GUH	300
164.	they speap	N	I	VC	635
165.	breal	N	I	L	420
166.	they loog	N	I	VC	705
167.	they plote	N	I	V	725
168.	they run	E	C	PRES. A	470
169.	tids	N	I	L	565
170.	pace	E	C	UL	230
171.	fure	N	I	L	365
172.	preed	N	I	L	400
173.	ponv	N	I	I	420
174.	they dug	E	C	PAST A	550
175.	forth-fourth	E	C	HEH	220
176.	lamg	N	I	I	600
177.	vein-vain	E	C	HUL	300
178.	they come	E	C	PRES. A	540
179.	seam-seem	E	C	HUH	425
180.	laugh	E	C	GSH	355
181.	quib	N	I	L	320
182.	large	E	C	UH	300
183.	they spent	E	C	PAST B	530
184.	glue	E	C	GSL	250
185.	flot	N	I	L	455
186.	belt	E	C	GUL	230
187.	gleap	N	I	L	320
188.	stair-stare	E	C	HEL	210
189.	they smope	N	I	VC	600

	List 1	E/N	C/I	Cycle 8	Duration
190.	twin	E	C	UL	250
191.	prind	N	I	L	450
192.	they find	E	C	PRES. B	450
193.	they hab	N	I	VC	655
194.	topk	N	I	I	425
195.	flirt	E	C	GSL	210
196.	read-reed	E	C	HUH	320
197.	plag	N	I	L	435
198.	they cleam	N	I	VC	700
199.	moisp	N	I	L	350
200.	core-corps	E	C	HUL	240
201.	they tell	E	C	PRES. B	460
202.	railg	N	I	I	555
203.	mesh	E	C	GUL	250
204.	worth	E	C	UH	230
205.	they courp	N	I	V	625
206.	none-nun	E	C	HEH	350
207.	crad	N	I	L	410
208.	blent	N	I	L	410
209.	creak-creek	E	C	HEL	325
210.	threp	N	I	L	250
211.	doubt	E	C	GSH	250
212.	they stung	E	C	PAST A	510
213.	care	E	C	GUH	210
214.	blean	N	I	L	250
215.	pask	N	I	L	400

	List 1	E/N	C/I	Cycle 9	Duration
216.	crisp	E	C	UL	300
217.	shed	E	C	GUL	180
218.	they mape	N	I	VC	500
219.	they sent	E	C	PAST B	580
220.	trum	N	I	L	200
221.	sult	N	I	L	300
222.	pail-pale	E	C	HEH	250
223.	sudf	N	I	I	320
224.	phase-faze	E	C	HEL	300
225.	clote	N	I	L	360
226.	bribe	E	C	GSL	380
227.	frese	N	I	L	395
228.	ail-ale	E	C	HUL	330
229.	lafp	N	I	I	255
230.	faith	E	C	UH	250
231.	drilk	N	I	L	310
232.	stick	E	C	CUH	300
233.	they flane	N	I	V	810
234.	leap	E	C	GSH	205
235.	lask	N	I	L	490
236.	they bring	E	C	PRES. B	520
237.	berth-birth	E	C	HUH	220
238.	clefe	N	I	L	210
239.	flast	N	I	L	490
240.	they sount	N	I	VC	600
					98,910

APPENDIX L: Program Print-Out (-Sample-)

HOMOPHONE EXPERIMENT (RUBENSTEIN/HENDORFF)

PROGRAM FOR LIST 1 WORDS

RESULTS FROM LIST 1

DATE: 1 18 1973

NAME: F.LEIBOLD

NUMBER	WORD	CYCLE	TYPE	SUBJECT RESPONSE	TEST WORD	RESPONSE COMPARISON	R.T.
1	THEY TAST	1	V	E	N	I	902
2	SON	1	MEH	N	E	I	1210
3	FANK	1	L	N	N	C	1789
4	PRAY	1	MEL	E	E	C	844
5	THEY THOUGHT	1	PAST	E	E	C	1089
6	MINT	1	GSL	E	E	C	934
7	QUELT	1	L	N	N	C	788
8	THEY SLING	1	PRES	E	E	C	1402
9	SIGHT	1	MUH	E	E	C	816
10	NESP	1	L	N	N	C	1086
11	FRAMK	1	I	N	N	C	1949
12	CLUP	1	L	N	N	C	868
13	PORK	1	UL	E	E	C	975
14	LEASK	1	L	N	N	C	1015
15	THEY GLITE	1	VC	N	N	C	1061
16	TEAR	1	MUL	E	E	C	756
17	MAINT	1	L	N	N	C	1182
18	TOHN	1	UH	E	E	C	774
19	THEY DRIVE	1	PRES	E	E	C	933
20	THEY BREAG	1	VC	N	N	C	1222
21	CRABG	1	I	N	N	C	1091
22	SCORP	1	L	N	N	C	1179
23	CRAFE	1	L	N	N	C	902
24	DUMB	1	GUL	E	E	C	850
25	COOK	1	GSH	E	E	C	643
26	BLOCK	1	GUH	N	E	I	968
27	THEY SMRANK	2	PAST	E	E	C	1153
28	SLEEM	2	L	N	N	C	1072
29	FLOE	2	MUL	E	E	C	713
30	RADSH	2	I	N	N	C	938
31	DRAHK	2	L	N	N	C	972
32	SMALT	2	L	N	N	C	938
33	BELL	2	MUH	N	E	I	800
34	PRIP	2	L	N	N	C	987
35	LOAF	2	GUL	E	E	C	973
36	HINK	2	GSL	E	E	C	1305
37	FLAMT	2	L	N	N	C	1275
38	THEY STRIDE	2	PRES	E	E	C	1724
39	HEAL	2	MEL	E	E	C	771
40	COVE	2	UL	E	E	C	1464
41	THEY VAULD	2	V	N	N	C	1573
42	FUZG	2	I	N	N	C	1154
43	LOAN	2	MEH	E	E	C	1036
44	BRAIN	2	UH	E	E	C	917

45	TRICK	2	GSH	E	E	C	1170
46	THEY COBE	2	VC	N	N	C	1300-2-
47	CLERT	2	L	N	N	C	992
48	KIND	2	GUH	E	E	C	823
49	PLACT	2	L	N	N	C	1143
50	THEY SELL	2	PRES	E	E	C	1160
51	THEY ROKE	2	VC	N	N	C	1168
52	SNATE	2	L	N	N	C	963
53	VIAL	3	HUL	E	E	C	1009
54	THEY RAN	3	PAST	E	E	C	969
55	SOLVE	3	UL	E	E	C	1139
56	KROZ	3	L	N	N	C	1372
57	GLAZB	3	I	N	N	C	1130
58	THEY COBE	3o	VC	N	N	C	1140
59	TRENE	3	L	N	N	C	819
60	WISE	3	UH	E	E	C	950
61	THEY SPEND	3	PRES	E	E	C	1263
62	MIFE	3	L	N	N	C	1541
63	THEY CAME	3	PAST	E	E	C	1187
64	MARP	3	L	E	N	I	909
65	SLAY	3	HEL	E	E	C	1122
66	BLAME	3	GSH	E	E	C	595
67	FLASP	3	L	N	N	C	1032
68	THEY CHARP	3	V	N	N	C	1227
69	THEY CANSE	3	VC	N	N	C	1362
70	STEAL	3	HEH	E	E	C	725
71	WESP	3	L	N	N	C	867
72	THEY DIG	3	PRES	E	E	C	1139
73	ANT	3	HUH	E	E	C	1057
74	FLEET	3	GUL	E	E	C	1024
75	PLAM	3	L	N	N	C	969
76	TUFK	3	I	N	N	C	1030
77	THEY REAZ	3	VC	N	N	C	1110
78	SWEAT	3	GSL	E	E	C	816
79	FALL	3	GUH	E	E	C	726
80	ROUND	4	UH	E	E	C	894
81	STUNE	4	L	N	N	C	983
82	JUDGE	4	GSH	E	E	C	963
83	THEY TOLD	4	PAST	E	E	C	1054
84	SINCE	4	GUH	E	E	C	805
85	THEY WORG	4	VC	N	N	C	1126
86	PAWN	4	GUL	E	E	C	945
87	TRUCP	4	I	N	N	C	1041
88	SLAND	4	L	N	N	C	1148
89	HAIR	4	HUH	E	E	C	766
90	STAIM	4	L	N	N	C	945
91	FIRSE	4	L	N	N	C	972
92	THEY FOUND	4	PAST	E	E	C	1072
93	SNEAP	4	L	N	N	C	840
94	THEY STING	4	PRES	E	E	C	1034
95	GREEL	4	L	N	N	C	762
96	GUILT	4	HUL	E	E	C	704
97	SLACK	4	UL	E	E	C	1444
98	JUME	4	L	N	N	C	823
99	THEY COUND	4	VC	N	N	C	1243
100	CHART	4	GSL	E	E	C	939
101	BREACH	4	HEL	E	E	C	764
102	CRAVB	4	I	N	N	C	851
103	WEAK	4	HEH	E	E	C	774
104	STRON	4	L	N	N	C	810
105	THEY SAMT	4	V	N	N	C	1074
106	THEY SLUNG	5	PAST	E	E	C	1203
107	PARK	5	GUH	E	E	C	715
108	GROVT	5	I	N	N	C	1108
109	GRAST	5	L	N	N	C	1145
110	THEY BROUGHT	5	PAST	E	E	C	1075

111	LEFS	5	VC	N	N	C	1399
112	FLAD	5	L	N	N	C	1035-3-
113	BEER	5	HUL	E	E	C	802
114	PEAL	5	HEL	E	E	C	780
115	GLANT	5	L	N	N	C	970
116	THEY THINK	5	PRES	E	E	C	947
117	SHART	5	L	N	N	C	841
118	NEED	5	HUH	E	E	C	1112
119	THEY MART	5	VC	N	N	C	1200
120	LUMP	5	UL	E	E	C	800
121	NAIT	5	HEH	E	E	C	704
122	PAINT	5	GSH	E	E	C	691
123	STRIG	5	L	N	N	C	784
124	THEY SEND	5	PRES	E	E	C	1089
125	BROWN	5	UH	E	E	C	756
126	THONB	5	I	N	N	C	1001
127	THEY CLASK	5	V	N	N	C	1489
128	QUARP	5	L	N	N	C	731
129	THEY DROVE	5	PAST	E	E	C	1198
130	BARP	5	L	N	N	C	951
131	PLOH	5	GSL	E	E	C	897
132	THEY SAILT	5	VC	N	N	C	1799
133	RASH	5	GUL	E	E	C	923
134	ROLT	5	L	N	N	C	864
135	THEY WRIKE	5	VC	N	N	C	1100
136	DUCK	6	GUL	E	E	C	764
137	CLIPE	6	L	N	N	C	689
138	PAIN	6	HUH	E	E	C	1082
139	BREEP	6	L	N	N	C	922
140	PLUM	6	HEL	E	E	C	821
141	THEY FELP	6	VC	N	N	C	1200
142	CRUSP	6	L	N	N	C	975
143	THEY SHRINK	6	PRES	E	E	C	1112
144	SLINT	6	L	N	N	C	811
145	JUICE	6	UH	E	E	C	683
146	THEY BLOP	6	VC	N	N	C	1010
147	JUMP	6	GSH	E	E	C	679
148	JUSK	6	L	N	N	C	795
149	THEY SOLD	6	PAST	E	E	C	1145
150	ROAST	6	GSL	E	E	C	840
151	CRESF	6	I	N	N	C	917
152	SAIL	6	HEH	E	E	C	685
153	FRAMP	6	L	N	N	C	807
154	HENT	6	L	N	N	C	1000
155	RYE	6	HUL	E	E	C	1394
156	THEY GEND	6	V	N	N	C	1217
157	GRIM	6	UL	E	E	C	999
158	THEY STRODE	6	PAST	E	E	C	1866
159	RUDK	6	I	N	N	C	1385
160	TYPE	6	GUH	E	E	C	1151
161	SHIFE	6	L	N	N	C	728
162	HORT	7	L	N	N	C	841
163	BLOH	7	GUH	E	E	C	753
164	THEY SPEAP	7	VC	N	N	C	1017
165	BREAL	7	L	N	N	C	716
166	THEY LOOG	7	VC	N	N	C	997
167	THEY PLOTE	7	V	N	N	C	910
168	THEY RUN	7	PRES	E	E	C	999
169	TIDS	7	L	N	N	C	746
170	PACE	7	UL	N	E	I	1156
171	FURE	7	L	E	N	I	2175
172	PREED	7	L	N	N	C	1220
173	PONV	7	I	N	N	C	1095
174	THEY DUG	7	PAST	E	E	C	1149
175	FORTH	7	HEH	E	E	C	1165
176	LAMG	7	I	N	N	C	1063

177	VEIN	7	HUL	E	E	C	918
178	THEY COME	7	PRES	E	E	C	877
179	SEAM	7	HUH	E	E	C	767
180	LAUGH	7	GSH	E	E	C	1074
181	QUIB	7	L	N	N	C	755
182	LARGE	7	UH	E	E	C	892
183	THEY SPENT	7	PAST	E	E	C	1158
184	GLUE	7	GSL	E	E	C	843
185	FLOT	7	L	N	N	C	765
186	BELT	7	GUL	E	E	C	1036
187	GLEAP	7	L	N	N	C	763
188	STAIR	7	HEL	E	E	C	785
189	THEY SMOPE	7	VC	N	N	C	1196
190	THIN	8	UL	E	E	C	1073
191	PRIND	8	L	N	N	C	948
192	THEY FIND	8	PRES	E	E	C	1069
193	THEY HAB	8	VC	N	N	C	1223
194	TOPK	8	I	N	N	C	774
195	FLIRT	8	GSL	E	E	C	762
196	READ	8	HUH	E	E	C	856
197	PLAG	8	L	N	N	C	883
198	THEY CLEAM	8	VC	N	N	C	1206
199	MOISP	8	L	N	N	C	1072
200	CORE	8	HUL	E	E	C	969
201	THEY TELL	8	PRES	E	E	C	927
202	RAILG	8	I	N	N	C	1069
203	MESH	8	GUL	E	E	C	914
204	WORTH	8	UH	E	E	C	892
205	THEY COURP	8	V	N	N	C	1004
206	NONE	8	HEH	E	E	C	861
207	CRAD	8	L	N	N	C	970
208	BLENT	8	L	N	N	C	1027
209	CREAK	8	HEL	N	E	I	762
210	THREP	8	L	N	N	C	880
211	DOUBT	8	GSH	E	E	C	1128
212	THEY STUNG	8	PAST	E	E	C	1281
213	CARE	8	GUH	E	E	C	751
214	BLEAN	8	L	N	N	C	814
215	PASK	8	L	N	N	C	1035
216	CRISP	9	UL	E	E	C	820
217	SHED	9	GUL	E	E	C	842
218	THEY MAPE	9	VC	N	E	C	1071
219	THEY SENT	9	PAST	NR	E	NR	3000
220	TRUM	9	L	N	N	C	844
221	SULT	9	L	N	N	C	1105
222	PAIL	9	HEH	E	E	C	874
223	SUDF	9	I	N	N	C	886
224	PHASE	9	HEL	E	E	C	849
225	CLOTE	9	L	E	N	I	786
226	BRIBE	9	GSL	E	E	C	860
227	FRESS	9	L	N	N	C	1010
228	AIL	9	HUL	E	E	C	902
229	LAFP	9	I	N	N	C	1063
230	FAITH	9	UH	E	E	C	816
231	DRILK	9	L	N	N	C	907
232	STICK	9	GUH	E	E	C	675
233	THEY FLANE	9	V	N	N	C	1126
234	LEAP	9	GSH	N	E	I	1997
235	LASK	9	L	N	N	C	925
236	THEY BRING	9	PRES	E	E	C	1017
237	BERTH	9	HUH	E	E	C	785
238	CLEFE	9	L	N	N	C	701
239	FLAST	9	L	N	N	C	986
240	THEY SOUNT	9	VC	N	N	C	1057

N: NONSENSE
E: ENGLISH
IN: INVALID NONSENSE
IE: INVALID ENGLISH
NR: NO RESPONSE
C: CORRECT
I: INCORRECT
IC: INVALID CORRECT
II: INVALID INCORRECT
ALL TIMES IN MILLISECONDS

TOTAL SUBJECT NO RESPONSE 1

TOTAL SUBJECT ENGLISH RESPONSE 117

TOTAL SUBJECT NONSENSE RESPONSE 122

TOTAL SUBJECT INVALID ENGLISH RESPONSE Ø

TOTAL SUBJECT INVALID NONSENSE RESPONSE Ø

TOTAL SUBJECT VALID CORRECT ENGLISH RESPONSE 113

TOTAL SUBJECT VALID CORRECT NONSENSE RESPONSE 116

TOTAL SUBJECT VALID INCORRECT ENGLISH RESPONSE 4

TOTAL SUBJECT VALID INCORRECT NONSENSE RESPONSE 6

AVERAGE TIME FOR VALID CORRECT RESPONSE TO ENGLISH TEST WORDS 959.43

AVERAGE TIME FOR VALID CORRECT RESPONSE TO NONSENSE TEST WORDS 1037.65

AVERAGE TIME FOR VALID INCORRECT RESPONSE TO ENGLISH TEST WORDS 1193.00

AVERAGE TIME FOR VALID INCORRECT RESPONSE TO NONSENSE TEST WORDS 1148.83

PERCENT VALID CORRECT RESPONSE TO ENGLISH TEST WORDS 94.96

PERCENT VALID CORRECT RESPONSE TO NONSENSE TEST WORDS 95.87

PERCENT VALID CORRECT RESPONSE TO TOTAL TEST WORDS 95.42

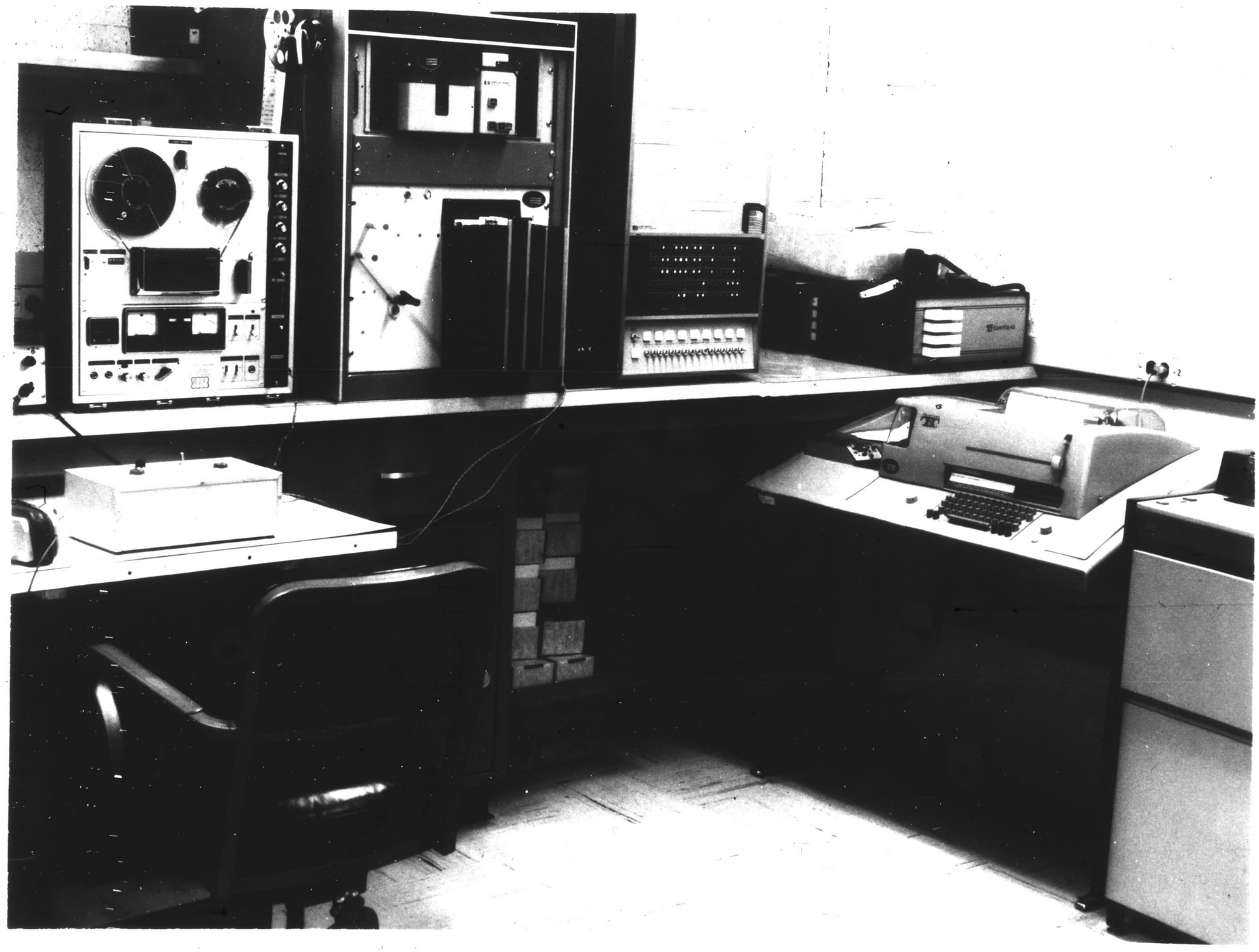
PERCENT VALID INCORRECT RESPONSE TO ENGLISH TEST WORDS 3.36

PERCENT VALID INCORRECT RESPONSE TO NONSENSE TEST WORDS 4.96

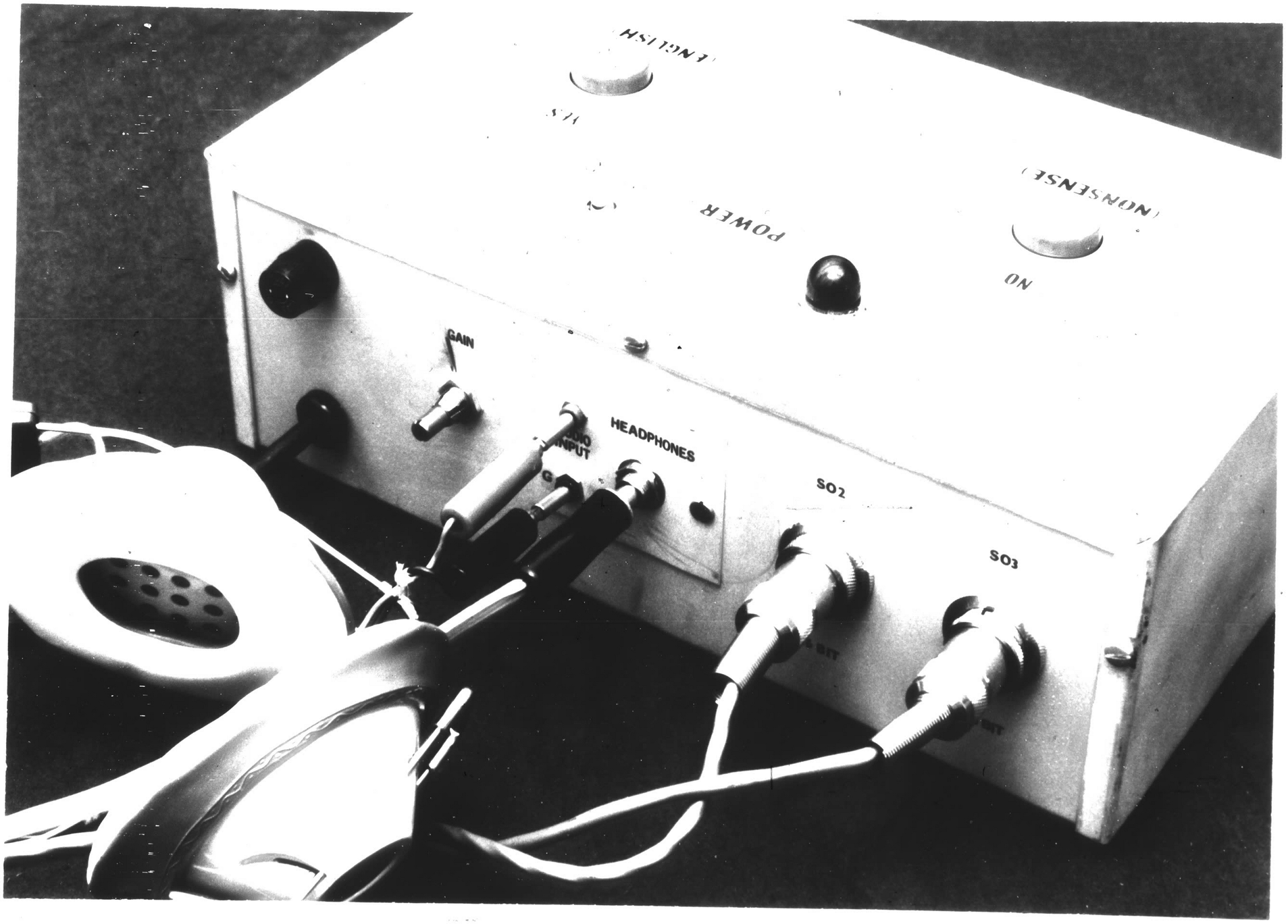
PERCENT VALID INCORRECT RESPONSE TO TOTAL TEST WORDS 4.17

PROGRAM COMPLETE

APPENDIX M: Photo 1 - Equipment Arrangement



APPENDIX M: Photo 2 - Voice Operated Electronic Relay



APPENDIX M: Photo 3 - Subject Being Tested

APPENDIX M: Photo 4 - Instructor and Subject During Test

ENGLISH VS. NONSENSE

TABLE I

TEST RESULTS OF RESPONSES	SUBJECTS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MEANS
TOTAL SUBJECT NO RESPONSE	0	0	1	1	0	1	0	0	0	2	1	1	1	3	1	3	1	2	1	3	1.10
TOTAL SUBJECT ENGLISH RESPONSE	123	117	120	119	119	121	122	127	128	124	125	123	117	125	121	124	127	124	124	125	123
TOTAL SUBJECT NONSENSE RESPONSE	117	123	117	118	119	117	116	113	112	112	112	116	122	109	116	112	111	113	114	111	115
TOTAL SUBJECT INVALID ENGLISH RESPONSE	0	0	2	1	1	1	1	0	0	1	2	0	0	1	2	1	0	1	0	1	0.75
TOTAL SUBJECT INVALID NONSENSE RESPONSE	0	0	0	1	1	0	1	0	0	1	0	0	0	2	0	0	1	0	1	0	0.40
TOTAL SUBJECT VALID CORRECT ENGLISH RESPONSE	119	108	118	117	118	118	117	120	120	119	118	119	113	119	118	119	120	119	119	118	118
TOTAL SUBJECT VALID CORRECT NONSENSE RESPONSE	115	111	117	116	118	116	114	113	112	112	112	115	116	109	116	112	111	113	113	111	114
TOTAL SUBJECT VALID INCORRECT ENGLISH RESPONSE	4	9	2	2	1	3	5	7	8	5	7	4	4	6	3	5	7	5	5	7	4.95
TOTAL SUBJECT VALID INCORRECT NONSENSE RESPONSE	1	12	0	2	1	1	2	0	0	0	0	1	6	0	0	0	0	0	1	0	1.35
AVERAGE TIME FOR VALID CORRECT RESPONSE TO ENGLISH TEST WORDS (ms)	623	826	609	674	604	541	687	715	694	699	765	644	959	739	614	584	655	686	759	771	692
AVERAGE TIME FOR VALID CORRECT RESPONSE TO NONSENSE TEST WORDS (ms)	839	887	1105	1173	1289	985	999	1288	1196	1152	1197	1043	1037	1171	1217	1112	1004	942	1162	1045	1045
AVERAGE TIME FOR VALID INCORRECT RESPONSE TO ENGLISH TEST WORDS (ms)	1265	863	734	1303	1371	1257	980	1364	1030	758	1204	810	1193	1199	889	1066	1404	1163	1253	1461	1128
AVERAGE TIME FOR VALID INCORRECT RESPONSE TO NONSENSE TEST WORDS (ms)	499	921	.0	838	1633	876	1633	.0	.0	.0	.0	1485	1148	.0	.0	.0	.0	.0	2171	.0	560
PERCENT VALID CORRECT RESPONSE TO ENGLISH TEST WORDS	100	91	99	98	99	99	98	100	100	100	99	100	95	100	99	100	100	100	100	99	98.8
PERCENT VALID CORRECT RESPONSE TO NONSENSE TEST WORDS	96	92	97	96	98	96	94	93	93	93	93	95	96	90	95	93	91	93	93	92	93.9
PERCENT VALID CORRECT RESPONSE TO TOTAL TEST WORDS	98	91	98	97	98	97	96	97	97	96	96	97	95	95	97	96	96	97	97	95	96.3
PERCENT VALID INCORRECT RESPONSE TO ENGLISH TEST WORDS	3.3	7.5	1.7	1.8	.8	2.5	4.2	5.8	6.7	4.2	5.8	3.3	3.3	5.0	2.5	4.2	5.8	4.2	4.2	5.8	4.1
PERCENT VALID INCORRECT RESPONSE TO NONSENSE TEST WORDS	.8	9.9	.0	1.6	.8	.8	1.6	.0	.0	.0	.0	.8	4.9	.0	.0	.0	.0	.0	.8	.0	1.1
PERCENT VALID INCORRECT RESPONSE TO TOTAL TEST WORDS	2.0	.7	.0	1.6	.8	1.6	2.9	.0	.0	.0	.0	2.1	4.2	0	.0	.0	.0	.0	2.5	.0	0.9

RESULTS FOR ALL CLASSES

TABLE II

	CYCLE CONSIST OF 16 CLASSES	FREQUENCY	ABBREVIATION	NUMBER OF STIMULUS WORDS	MEAN WORD FREQ	MEAN NO. OF LETTERS	% CORRECT RESPONSES	AVERAGE ADJUSTED RESPONSE TIME (ms)	DURATION	ENGLISH VS. NONSENSE (MS)	MEAN FAMILIARITY
ENGLISH	(1) HOMOPHONE EQUIPROBABLE	LOW	HEL	9	129	4.5	97	367	366		4.7
	(1) -"- -"-	HIGH	HEH	9	593	4.1	98	319	320		3.6
	(1) HOMOPHONE UNEQUIPROBABLE	LOW	HUL	9	169	3.9	97	342	342		4.4
	(1) -"- -"-	HIGH	HUH	9	725	4.1	99	331	328		3.4
	(1) HOMOGRAPH SYSTEMATIC	LOW	GSL	9	93	4.6	99	320	319		4.3
	(1) -"- -"-	HIGH	GSH	9	772	4.7	97	316	318	332	3.7
	(1) HOMOGRAPH UNSYSTEMATIC	LOW	GUL	9	97	4.1	98	356	355		4.4
	(1) -"- -"-	HIGH	GUH	9	908	4.3	98	291	290		3.5
	(1) NONHOMONYM	LOW	UL	9	124	4.3	96	398	394		4.6
	(1) -"-	HIGH	UH	9	849	4.8	98	316	317		3.3
	(1) PRESENT TENSE	L/H	PRES A/B	15	1588	4.5	99	307	306		3.9
	(1) PAST TENSE	L/H	PAST A/B	15	1374	4.8	99	313	320		4.1
NONSENSE	(1) NONSENSE WORD		V	9		4.7	96	646	611		
	(1) NONSENSE WORD (RESEMBLING ENGLISH)		VC	20		4.4	93	660	659	648	
	(2) ILLEGAL NONSENSE WORDS (PRONOUNCEABLE)		I	18		4.6	100	660	666		
	(8) LEGAL NONSENSE WORD		L	71		4.6	94	626	639		
				238		4.4	97	411			

TABLE III

HOMONYMIC HYPOTHESES

HYPOTHESIZED	OBTAINED ADJ RT IN MSEC.	
1. RT (HEH) < RT (UH)	319 > 316	REVERSAL
RT (HEL) < RT (UL)	367 > 398	
2. RT (HEH) < RT (HUH)	319 < 331	
RT (HEL) < RT (HUL)	367 > 342	REVERSAL
3. RT (GUH) < RT (UH)	291 < 316	
RT (GUL) < RT (UL)	356 < 398	
4. RT (GUH) < RT (GSH)	291 < 316	
RT (GUL) < RT (GSL)	356 > 320	REVERSAL

TABLE IV

HOMONYMIC HYPOTHESES WITH COMPENSATED RT

HYPOTHESIZED	COMPENSATED ADJ RT IN MSEC.	
1. RT (HEH) < RT (UH)	319 < 331	
RT (HEL) < RT (UL)	367 < 403	
2. RT (HEH) < RT (HUH)	319 < 341	
RT (HEL) < RT (HUL)	367 > 357	REVERSAL
3. RT (GUH) < RT (UH)	291 < 326	
RT (GUL) < RT (UL)	366 < 398	
4. RT (GUH) < RT (GSH)	301 < 316	
RT (GUL) < RT (GSL)	356 > 325	REVERSAL

FOOTNOTES

1. This work was accomplished while Prof. H. Rubenstein, Lehigh University, was the initiating force behind the project conducted at the Western Electric Company in Reading, Pennsylvania. Appreciation is expressed toward Lehigh University's Staff for guidance and advice and to the Western Electric Engineers for their generous help and participation. We thank L.D. McMahon and D.E. Meyer, Bell Telephone Laboratories, for their support and G.B. Loughery and H.N. Schappell for helping with the apparatus.

2. Here and elsewhere we are reporting RT differences plus-or-minus one standard error.

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VITA

Erwin Wendorff, son of Albert and Mary Wendorff, was born in Beuthen U.S. in 1921. In 1939, he received a B.A. in Liberal Arts from Beuthen College. In 1952, he received a B.S.M.E. in Engineering from Reuthlingen College of Engineering.

His early professional experience was with Western Electric Co., Inc. as an Engineer to conduct reliability evaluation of mechanical systems, design and development of future models, effects analyses, stress analyses and tolerance studies.

His later professional experience was with Bell Telephone Laboratories Inc. connected chiefly with Development work on the Universal Integrated Communication System including computer systems.

From 1968 until 1973, when he was admitted as a graduate student in Information Sciences at Lehigh, he was a Senior Development Engineer at Western Electric Co., Inc. in Reading, Pa.

His major interest there is in conducting studies in experimental psychology as applied to the optimal design of machines and tasks and evaluation of a survey of human capacities and limitations. Currently he is working on problems of information input, information processing and decision making experiments for the human operator.

Publications and Talks:

1. The "Certificate of Merit" received from Western Electric Co., Inc. in recognition for adopted procedures in effects analyses studies. Issued by the North Carolina Works in June, 1963.

2. The "Certificate of Appreciation for Excellence in Teaching", issued by the Bell Telephone Laboratory, Inc. Department of Education, received from Dr. J. N. Shive, Director B.T.L. Murray Hill, N.J. in July, 1966.

3. "Component Reliability and Failure Patterns in Military Systems". Presentation given at the "Technische Zuverlässigkeit 1967". Meeting in Nürnberg, Germany, May, 1967.

4. The "Certificate of Appreciation for Excellence in Teaching", issued by the Bell Telephone Laboratory, Inc. Department of Education, received from Dr. J. N. Shive, Director B.T.L. Murray Hill, N.J. in July, 1967.

5. The "Certificate of Appreciation for Excellence in Teaching", issued by the Bell Telephone Laboratory, Inc. Department of Education, received from Dr. J. N. Shive, Director B.T.L. Murray Hill, N.J. in July, 1968.

6. "Mechanical reliability analysis program for the Towed System on nuclear submarines". A paper presented on the mechanical reliability program to the Towed Array Review Panel representing the Navy and the prime conductor, Electric Boat. Groton, Conn., June, 1968.

7. "Machine Translation of Natural Languages", 9th WECO Engineering Symposium, B.T.L. Whippany, N.J., invited talk, March 1969.