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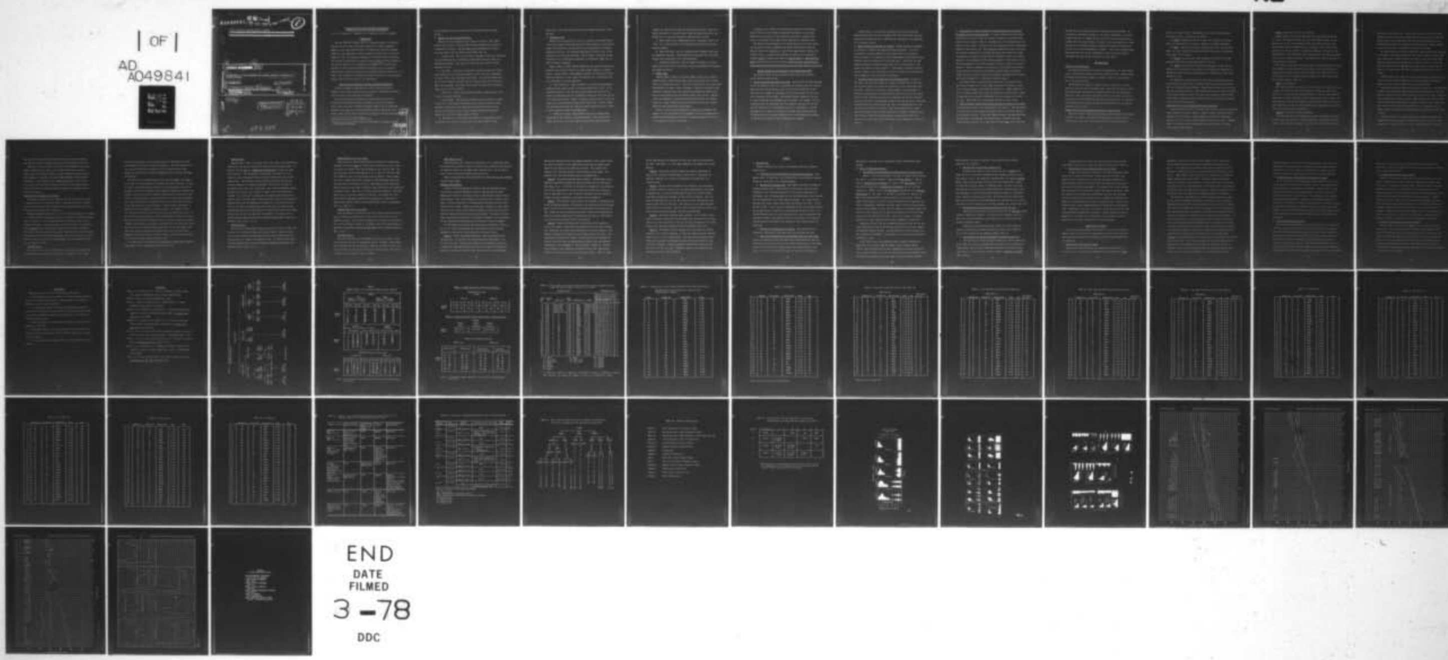

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AN INVESTIGATION OF SOME TECHNIQUES FOR TRAINING OPERATORS IN THE SKILLS OF PASSIVE LISTENING.

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An Investigation of Some Techniques for Training Operators in the Skills of Passive Listening

D. W. J. Corcoran,* A. Carpenter, J. C. Webster,** and M. M. Woodhead

INTRODUCTION

The work described herein is part of a program assigned to the Medical Research Council's Applied Psychology Research Unit (APRU), Cambridge, England, by the Sonar Sub-Committee of the Royal Naval Personnel Research Committee. The experimental work was conducted at APRU and the report was prepared at NEL. The program is designed to investigate factors affecting the training and performance of sonar operators engaged in passive listening. The specific purpose of the experiments reported here is to question the validity of certain training techniques incorporated into an automatic teaching device designed by Elliott at the Admiralty Research Laboratory (ARL). This memorandum is intended for limited circulation to those persons having a need for early access to the information.

CERTAIN RELEVANT ASPECTS OF THE REAL LISTENING ENVIRONMENT

In order to judge the applicability of the listening situations employed in the present experiments, some background information about the real environment of the sonarman is necessary.

The sound reaching the sonarman may be conveniently classified as evolving from three major sources: (1) ambient sea noise and platform noise, which result from a number of different factors and are invariably present in some degree; (2) cavitation noise, which if present may take several forms; and (3) engine noise, which usually has the least amplitude.

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at the hydrophone and may be partially or totally masked by the other sources.

1. Ambient sea noise and platform noise

Ambient sea noise originates from a number of sources. Wenz (1962) details these sources and Halley (1962) has generalized Wenz's results in a handbook for sonarmen. The following summary statements are derived from Wenz (1962), Fig. 13; and/or Halley (1962), Fig. 19.

a. Thermal noise. This is the result of movement of the water molecules. It is predominantly high in frequency, rising about 6 dB per octave with increasing frequency. This noise has a level of about -20 dB re .0002 microbar at 10 KC.

b. Sea state. Winds have a considerable effect upon the state of the water surface and the resulting increase in noise level at the hydrophone is about 5 dB for every doubling of wind speed. At 1 KC the residual minimum is about 15 dB and a 20 knot wind will increase this level to about 37 dB at this frequency. The effect of wind speed is mainly in the frequency region between .5 KC and 100 KC.

c. Heavy rain. Heavy rain may raise the ambient level between .5 and 10 KC to levels of 52-57 dB.

d. Ship traffic. Non-target ship traffic has been estimated to cause as much as a 40 dB increase in ambient level in densely populated waters. The higher frequencies which ships emit are attenuated readily in the water, so the resultant noise at the listening hydrophone is greatest between .01 and 8 KC, reaching levels of 70 dB.

e. Platform noise. The noise of the engines, the propellers and the flow noise of the parent ship depends upon too many factors to allow description. This source may be very loud and highly troublesome to the sonarman.

2. Cavitation noise

Cavitation is considered to be due to a reduction in pressure behind a revolving propeller blade such that the dissolved gases in the sea water expand into bubble-like cavities which collapse impulsively when normal pressure is restored. The frequency amplitude and "on-off" cycle of the cavitation vary with speed and depth. This is often a component of platform noise, but is sufficiently important as a detectable signal that it will be treated separately.

Halley (1962, p. 64-71) defines "blade tip" and "sheet" cavitation and shows how the cavitation spectra vary with speeds anddepth of a target vessel. Elliott (1965) of ARL suggests five types of cavitation of which three are modulated in some regular time pattern, one is continuous, and one irregularly and rapidly modulated:

a. Light cavitation. Light cavitation is a relatively high-pitched modulated noise (about 1.5 KC) in which the on-off ratio is low. It is probably equivalent to what has been called "blade tip cavitation" in which the relatively slow rate of propeller revolution causes only the tip of the blade to cavitate. Seldom are blades perfectly matched so that one blade will normally begin cavitating before the others. When all blades are cavitating this blade will yield the highest amplitude sound, so that a clear repeating rhythm is distinguishable.

b. Medium cavitation. This probably occurs when a fairly large proportion of the propeller is producing bubbles. This causes both a higher on-off ratio and a lower basic frequency than light cavitation owing to the formation of larger and more abundant bubbles. There is no strict distinction to be drawn between light and medium cavitation; one merges into the other with changes in speed and other factors.

c. Heavy cavitation is unmodulated and has a frequency around .1 to .2 KC. It is characteristic of fast-moving military vessels with good propeller blades.

d. Hard cavitation. This is a continuous low frequency noise which is irregularly modulated. Hard cavitation is characteristic of merchant vessels whose propellers are not well-maintained.

e. Compressed cavitation. This is "light" in having a low on-off ratio, but is more "tonal" in quality and has been described as "chirping." Its origin is unknown.

3. Engine noise

Elliott (1965) of ARL has classified engine noises into six kinds: rhythmic diesel, reciprocating steam, diesel roar, diesel whine, turbine whine and electric motor whine. These fall naturally into the gross triple classification of whines, roars and rhythms: Whines are composed of high frequency, relatively pure tones, usually in harmonically related sets. Roars are unmodulated noise with fairly sharply tuned spectra. Rhythms, as the name suggests, are discontinuous patterned noises; the rhythmic diesel has a single regular beat which contrasts with the more complex pattern of the reciprocating steam engine.

The hull of the ship is considered to function as a resonator and radiator so that the quality of the propagated sound will depend upon the structural characteristics of the hull and engine placements as well as on the proportion of hull under water.

In general, such factors as the distance and depth of the listening vessel relative to the "target," temperature distribution in the water, salinity, and the nature of ocean floor all contribute to produce variations in the quality of the engine sounds reaching the sonarman's ears.

The above very brief summary of the characteristics of the real listening environment serves to emphasize the extreme difficulties facing the sonarman when he is attempting to classify the engine which is driving the "target" vessel. In general, his task can be summed up as an attempt to recognize types of engines when these are heavily masked by semi-structured noise and when there may well be enormous variation in the characteristics of the same type of vessel and even the same vessel under different conditions.

THE ARL PROGRAM AND ITS RELATION TO THE PRESENT EXPERIMENTS

The characteristics of the ARL program which it was felt desirable and practical to question were:

1. Are the proper verbal labels being used? Verbal labels are used copiously in the ARL program in order (a) to orientate the listener toward the relevant sound and away from the masking noise, (b) to point out features of the sound which are thought to distinguish it from other sounds, and (c) to aid in the retention of the sounds. The possible hazards involved in the use of verbal labels may well outweigh their advantages. For example: (1) The trainer may fail to communicate with the trainee or may even give him "incorrect" information by an unfortunate choice of a descriptive. (2) The programmer may be wrong in his choice of relevant sound characteristics. (3) Labels may actually impair retention of a sound by causing the trainee to "squeeze" his experience into an inappropriate category.

A large portion of the present experiments has been concerned with labels supplied both from the synthesizer (who "knows the rules") and from experienced listeners who can be considered to correspond to the programmer of the teaching trainer.

2. Should training be "massed" or "spaced"? The ARL program is something of a mixture of "massed" and "spaced" training techniques. One of the experimental conditions employed in the present study is an attempt to discover whether it is possible to obtain improvements in performance using different orders of presentation of training items. Since there are many degrees and kinds of massing and spacing it has not been possible in the present experiments to sample them all. Accordingly a "sensible" ordering has been compared with a random one, in order to establish the general fact that ordering of items can influence performance.

3. How much ambient noise should be on the training sounds? In general, the items used in the ARL program were "good" recordings in the sense that the available library was scanned for recordings in which the engine noise was clear. This may or may not be a good procedure, since although the trainee is presented with a relatively clear sound from which he may obtain rich and useful information, he may be ill-prepared for the more difficult practical situation. Alternatively, it may be the case that quite unrealistic recordings should be used which are far freer of masking noises than would normally be encountered in practice. With these considerations in mind most of the engine sounds used for training in the present experiments were rather heavily masked by cavitation noise, but some engine sounds were noise-free, and some had a high ratio between engine (Signal) and cavitation (Noise).

4. <u>Is knowledge of results (feedback) or cueing (giving the name before the sound) the best training method?</u> At certain stages in the ARL program the trainee is required to make an attempt to classify a sound before the correct answer is given. This is a necessary part of the program since the trainee is not allowed to proceed to the next stage until he has demonstrated mastery of the previous one. The experiment reported here seeks to discover the relative effectiveness of "cueing" (giving the name before the sound) as opposed to knowledge of results (KR) or "feedback" in which the subject guesses at the classification before being given the correct answer in order that the programmer may use these methods as little or as much as they are required. Cueing vs feedback, or knowledge of results (KR) has been shown to be important in training for perceptual tasks by Annett and Clarkson (1964), who say "cueing was found to be effective, sometimes more effective than KR in training (to) ...identify an auditory signal."

Four other studies are also directly relevant to the present report. Two studies by Swets et al. (1962, 1966) have shown an advantage in favor of the cueing procedure, but studies by Sidley et al. (1965a, 1965b) and Weisz and McElroy (1965) have shown that feedback is as effective as cueing if exposure of the stimulus is sufficient for it to overlap in time with the name. These facts will be considered further at a later stage.

5. <u>What is learned: engine types or only the specific example of the type?</u> The ARL program consists of a training and a test session. The test session is structured to provide further training as well as to test the success of the previous session. In the test session, however, the same recordings are used which were presented as training items. A correct test item could therefore indicate not so much that the engine <u>type</u> had been learned

but that the actual recording used for training had been memorized. It was therefore considered necessary in the present experiments to construct a large population of "engine" sounds, so that the test recordings could contain items never heard before. In order to keep the procedures as close as possible to the machine program, training was conducted entirely with the use of a very small population of sounds. A few of the training sounds were "injected" into the test recordings in order to discover whether "training" items were better identified than test items.

THE EXPERIMENTS

Training and test material

Two separate populations of sounds were synthesized: (1) five masking noises, simulating cavitation, and (2) one hundred and four "engine" noises. The engine and cavitation sounds were mixed, to make up a total library of 5 x 105 (520) mixtures.

The proportion of engine, or signal, sound to cavitation, or noise, sound was varied as will be described later. This ratio of signal to noise will hereafter be referred to as the Signal/Noise ratio and abbreviated S/N ratio. Note that ambient sea noise as such is not mixed in. This is because this is a classification task, NOT a detection task. By definition the engine/cavitation sound is already above the ambient sea noise before classification can occur.

Characteristics of the synthesized cavitation sounds (noise)

The five cavitation noises were produced by passing white noise through a formant type filter. This has a peak transmission 4 dB above that at low frequencies, and above the formant peak the response approached a slope of -12 dB per octave. Spectrograms of the five cavitation noises are shown in Fig. 1. Details of each follow:

(1) "Heavy" cavitation consisted of noise with spectrum as described above, the peak being set at 150 cps. There was no further modulation.

(2) "Hard" cavitation was produced with the same filter setting as for Heavy, the output being 80% amplitude-modulated with a very low frequency noise signal (0.1 to 5 cps).

(3) "Medium" cavitation had a peak frequency of 300 cps and was 50% amplitude-modulated by a sinusoidal signal at 2.5 cps.

(4) "Light" cavitation had a higher peak frequency, 600 cps, and the modulation, by the same 2.5 cps sine wave, was increased in magnitude and "backed off" until the noise signal consisted of shaped pulses with an on-off ratio of 1.2.

(5) "Compressed" cavitation had the same filter setting and modulation characteristics as Light, but a "chirping" quality was produced by passing part of the modulated signal through a sharply tuned filter, set at 1200 cps and with a bandwidth of 20 cps. The ringing output of this filter was added to the Light cavitation noise in an amount which produced an easily recognized change in subjective quality although there was no appreciable change in an overall level measurement.

Characteristics of the synthetic Engine noises (signals)

A gross description of the 104 engine noises and their response categories (names assigned) is shown in Table 1. Table 1 contains only the relevant parameters of the stimuli. Detailed physical parameters and the names assigned to each are given by engine number in Tables 2, 3, and 4. Spectrograms of 14 representative engine noises are shown in Fig. 2. Details of the engine noises follow:

Whines (called Albert, Bertie, or Charlie)

Whines originated in a pulse generator with a line spectrum uniform to 3 kcps. The repetition rates were, for "low pitched" whines, 52, 100, and 125 pps, and for "high pitched" whines, 160, 205 and 245 pps. The pulse signal could be modulated either in frequency (with a deviation of ± 10 pps at a rate of 4 cps) or in amplitude (30% s.m. at 6 cps), or both simultaneously. The ummodulated pulse signal and that with frequency modulation only were defined as "Smooth." Both modulations together produced the signal defined as "Rough."

This pulse signal, either Smooth or Rough, was given a further dichotomy, into "Rounded" or "Edgy" by band-pass filtering. For sounds defined as Rounded, the frequency ranges passed were either 40 to 450, 40 to 600, or 225 to 1250 cps. For the Edgy sounds the ranges were either 450 to 2500, 320 to 5000, or 1250 to 5000 cps.

Roars (called Douglas)

Roars were produced by passing white noise through a formant filter with a higher "Q" value than that used to produce the cavitation noises (the peak was + 10 dB re the low frequency response). The high peak amplitude emphasized the chosen frequency to give a tonal quality to the sound. The peak frequencies were split arbitrarily into "Low" and "High": Low Roars had peak frequencies of 120, 140, 160 and 180 cps; and High Roars had peak frequencies of 200, 220, 250, and 300 cps.

Rhythms (called Eric, Freddie and George)

The signal from which the "rhythms" were made was produced as follows: The pulse generator was set to a rate of 57.5 pps. Six groups of sharply tuned resonant filters were tuned to the 2nd, 4th, 5th, 6th, 8th and 10th harmonics of this pulse tone. In each case either two or three resonant filters were used, the Q being between ten and forty, so that the selected harmonic output was perceptually a pure tone with no modulation at the fundamental frequency. The bandwidth of these groups of resonant filters was not measured, but was probably in the region of 10 cps.

The pulse excitation was then removed and a white noise source connected in its place. The filter outputs were then bands of noise, so narrow that they sounded like randomly modulated pure tones. These tones when added produced a true scale common chord with the third on top, i.e., 115, 230, 288, 345, 460 and 575 cps (B^b_2, B^b_3, D_4, F_4, B^b_4, and D_5). However, as the tones had a random source there was a pronounced reverberant or "choir" effect.

"Mixed" Rhythms used either all six components together (harmonics 2, 4, 5, 6, 8 and 10) or only harmonics 5, 6, 8 and 10; "single" Rhythms used either the fifth harmonic (288 cps) or the tenth (575 cps).

From these signals the Rhythm was obtained by modulation. The modulating voltage was obtained photoelectrically from a rotating cardboard cam; thus both the amplitude and the tone relations of the bursts of signal constituting the rhythm could easily be varied. Both variables were used, so that in the Double Rhythm a loud burst of signals was followed by a quieter one, with a relative pause before the next loud burst. Similarly, with the Triple Rhythm, a loud burst was followed by two less loud bursts, and then a pause.

For each rhythm there were two paper cams, nominally the same, but inevitably differing in detail. Similarly, there were two rates of presentation, produced by turning the cam at different speeds. Neither of the two latter variations had any influence upon the correct response, and these factors will be lumped together for the remaining discussion.

Reference to Table 1 will show that there were altogether seven basic types of engine noises: Albert, a low pitched smooth whine, Bertie, a high pitched smooth whine; Charlie, a rough whine whose pitch was irrelevant; Douglas, a roar; Eric, a single rhythm; Freddie, a double rhythm; and George, a triple rhythm. The rounded-edgy dimension of the whines, the pitch of the roars and the harmonic structure of the rhythms made it possible to define the fourteen possible categories of response shown at the base of Table 1.

Construction of training and test tapes

The general procedure used on making up the tape recordings was to mix an engine sound with a cavitation sound at a suitable S/N ratio. The S/N ratio selected for each mixture depended upon experimental conditions, upon the engine noise and upon the cavitation.

Twenty-eight engine noises (two each of the 14 distinct types) were chosen to be representative of the population, and each engine was randomly combined with a cavitation. The twenty-eight mixtures so formed were used in all training recordings. All engine noises were used twice but the cavitation-engine mixtures were never repeated except in a few instances for Roars. The order in which the mixtures were played, determined by a random procedure, was constant for all training recordings but one. Test recordings were constructed in the same way as the training tapes, i.e., two examples of each type of engine were used.

Training Tape 1

The sounds and the order in which they were assembled on Training Tape 1 are described on the left side of Table 5. In Tables 3, 4 and 5 each

each of the 104 engine sounds, including the 28 on Training Tape 1 (TT1) is described in terms of its relevant parameters. Each item lasted for 15 sec. and was followed by an interval of 15 sec. before the next item. During the intervals between items the name and name only of the next item was inserted.

The S/N ratio was "realistically low" in that the engines were judged to be about as heavily masked as in the practical sonar situation. In order to reach a "realistically low" S/N ratio the two synthesizers listened to an engine noise free of masking and then gradually introduced the masker and reduced the S/N ratio until the relevant characteristics could just be perceived. Both the engine and cavitation type used in the mixture influenced the chosen S/N ratio; thus considerable variations in the numerical value of the S/N ratios can be seen in Table 5. Figure 3 shows spectrograms of typical mixtures of engine and cavitation noises. One example is shown for each type of cavitation noise and, in fact, the examples are items 1, 2, 3, 4, and 5 of training tape 1. It must be remembered, however, that each S/N ratio was subjectively equivalent, i.e., the value at which the relevant "engine" characteristics could just be perceived above the "cavitated" noise. Note that the value of S/N is always negative; i.e., the experimenter perceived the engines in physical S/N levels where most of the measurable physical energy was the noise. In fact, in Fig. 3 it isn't always visually obvious that an engine noise is present at all.

In summary, TT1 is characterized by Name Cueing, No Knowledge of Results (KR), Random order, and Difficult S/N, or NC, -, R, D.

Training Tape 2

Training Tape 2 (TT2) was an exact copy of TT1 except in the information contained in the intervals between the sound mixtures (training items). In TT2 both the name and the "synthesizer's description" occupied the inter-sound interval. The "synthesizer's description" consisted of a set of adjectives whose meanings had been previously defined during the pre-test instructions. The adjectives had been carefully chosen to describe the relevant parameters as closely as possible. They were not acoustic or electronic terms; some, e.g., "high pitch," were common descriptives, while the meaning of others, e.g., "mixed" or "edgy," had to be accepted and learned. It is important to distinguish the "synthesizer's descriptions" from the terms to be used later in the "experienced listener's descriptions." The main feature of the synthesizer's descriptions was that they were as close to the truth as language would allow since they were chosen by the experimenters, who had full knowledge of the physical structure of the sounds and the rules by which the qualities were combined. In summary, TT2 is characterized by Synthesizer's-Description-Cueing, No KR, Random order, and Difficult S/N, or SDC, -, R, D.

Training Tape 3

The sounds in Training Tape 3 (TT3) are identical to those in TTs 1 and 2 except that the order of items was no longer random. Table 6 presents the new order, which was designed such that each sound differed from its predecessor by one relevant characteristic only. In summary, TT3 is characterized by Synthesizer's-Description-Cueing, No KR, Ordered items, and Difficult S/N, or SDC, -, O, D.

Training Tapes 4a, b, c, d, and e

These tapes were like TT2 except that the synthesizer's description occupied the interval after the sound rather than before it; thus instead of cueing, the listener would have knowledge of their results (KR). The only difference between recordings 4a, b, c, d, and e was that each began at a different point in the item order shown in Table 5. Tape 4a began with item 4 (Engine number 60), proceeded to item 28 (Engine number 70), and then went on with items 1, 2 and 3. Thus Tape 4a had 28 items which were in almost the same order as previous tapes, but started and finished at a different point. Tapes 4b, c, d and e started and finished at different points but were otherwise identical to Tape 4a. In summary, TTs 4 are characterized by No Cueing, Synthesizer's Description as Knowledge of Results (KR), Random (though systematically shifted items), and Difficult S/N, or _, SDKR, O, D.

Training Tapes 5a, b, c, d and e

These recordings were identical with Tape 2 except in their S/N ratios. Tape 5a contained no masking at all, and in 5b to 5e the S/N ratio was gradually reduced. The S/N ratios employed in these tapes are presented in the last five columns of Table 5. In summary, TTs 5 are characterized by Synthesizer's Description Cueing, No KR, Random order, and Varying S/N, or SDC, -, R, V.

Test Tapes i to x

Each Test Tape contained two examples of each type of engine. Items were of 15 sec. duration and separated by 15 sec. of quiet. Realistically low S/N ratios were used in all tapes. Three or four items in each tape were identical with certain items used in the Training Tape. Full details of Tapes i to x are given in Tables 7 to 16.

Test Tapes ia to va

These recordings were identical to Test Tapes i to v, except that there was no cavitation present on Tape ia. Cavitation was introduced and increased in amplitude relative to the engine level from iia to va. The S/N ratios can be found in the final columns of Tables 8 to 11.

Table 17 summarizes all the characteristics of the training tapes (TrngTs) and test tapes (TsTs).

Subjects and Procedures

A total of 81 Naval Ratings were tested; none were included who were found to have a hearing deficiency likely to interfere with the task. Subjects were tested in sub-groups of six in semi-secluded cubicles fitted with earphones. Ten 40 min. sessions were conducted over a period of five days. A session consisted of a fifteen-minute training period and a test period of equal length. Subjects recorded their responses on answer sheets and at the end of each session they were allowed to mark their own sheets (suitable measures being taken to prevent cheating). The number of correct items was plotted on graph paper and displayed throughout the ten sessions, so that subjects and experimenter had an up-to-date record of progress.

The 81 subjects were divided into eight groups, designated A, B, C, D, E, F, G, H. Table 18 summarizes the experimental training conditions employed on these groups. More details for each group follow:

Group A. Group A comprised 12 subjects. They were presented with Training Tape 1 in the first half of each session and Test Tapes i to x in the latter half. Subjects were told that the recordings consisted of a signal and a masking noise and that they had to ignore the maskers and attempt to identify the signals by the names given on the Training Tape.

The fourteen possible answers were always displayed on their answer sheets. No questions addressed to the experimenter concerning the relevant parameters to which they should listen were answered. The procedure was repeated over a two-week period of twenty sessions on this group. The results of the first ten sessions only are considered here.

Group B. This group contained eleven subjects. Training Tape 2 (synthesizer's descriptive cueing) was used for training and was followed by Test Tapes i to x. In addition to the general instructions, this group was given a full description of the way in which the sounds were constructed and the rules they were to use to come to a decision, and were allowed to consult the logical breakdown of the sounds shown in Table 18.

Group C. The procedure used in Group C was a mixture of procedures used on the two preceding groups. This group of six subjects was given Training Tape 1 for the first five sessions and Training Tape 2 for sessions six to ten. Before the first session they were given instructions appropriate to Group A and before Session Six the instructions for Group B. Test Tapes i to x were used in the latter half of each session.

Group D. During the training part of each session the subjects in Group A were asked to record their own descriptions of each type of sound. This instruction was carried out faithfully by the greater majority of the subjects, although some preferred to use diagrams rather than words. The descriptions recorded after fifteen to twenty sessions were examined and the most valid (the ones corresponding most closely to the synthesizers' descriptions) were displayed on a sheet identical to Table 19. Group D, which comprised twelve subjects, was presented with these "experienced listeners' descriptions" and trained on Training Tape 1. They were told how the descriptions had originated and that they would be well-advised to use them. Test Tapes i to x were again employed in the second half of each session.

Group E. This group of eleven subjects was treated identically to Group B, but listened to Training Tape 3 rather than 2. This group was therefore comparable to B except in receiving the training items in a different order.

Group F. Group F, which consisted of five subjects, was instructed in an identical fashion to Group B, but were given supplementary instructions to prepare them to receive training tapes in which the S/N ratios would start high and gradually decrease over the first six sessions. They were given Training Tapes 5a, b, c, d, and e over the first five sessions, followed by Tape 2 for the last five. Test Tapes i to x were used during the latter part of each session. Thus the "easy" training schedule on the first five sessions was matched against difficult test recordings.

Group G. This group contained twelve subjects. It was treated identically with Group F except that the Test Tapes used from session one to five were ia, iia, iiia, iva and va. The easy training recordings of the earlier sessions were therefore accompanied by correspondingly easy tests.

Group H. This group of twelve subjects was tested similarly to Group G except in the last five sessions, in which the subjects received Training Tapes 4a, b, c, d and e, respectively. When presented with Training Tape 4 they were requested to anticipate the name of the sound before it came over their earphones. Group H, therefore, differed from Group G only in the final five sessions, when a "feedback" procedure was substituted for the cueing procedure used on Group G.

RESULTS

A. Measures used

Whenever possible, four indices of performance have been extracted from the data:

1. Percentage of correct responses on the last five sessions. This measure gives an indication of the absolute levels of performance attained during the latter half of the training program.

2. The saving in training time. This measure indicates the number of training sessions under a given condition X required to reach the final performance level of another condition Y. The index is expressed as a percentage, thus a p% saving means that the final performance level achieved by Y was reached by X on or about session (10-p/10). As a visual aid to obtaining this index, linear curves have been fitted to the data. As will be seen in Figs. 4 to 7, the linear assumption is not too seriously violated. The savings measure is probably the most important criterion, since (a) it is less dependent upon the actual materials used in these experiments than the absolute levels of performance and (b) it is related to the amount of teaching machine time likely to be required to reach adequate levels of attainment.

3. The rate of improvement over sessions. This measure has been assessed by comparing the first three with the last three sessions.

4. The relative probabilities of recognizing "new" and "old" items. It will be recalled that the test tapes were constructed mainly from mixtures which had never been used in the training recordings; in a few cases, however, items used in the training tapes were inserted into the test tapes. The precise index used to assess the ability of the subject to

generalize to new items was the proportion % Items correct/% Old items correct.

B. Effect of training procedures

1. The influence of descriptives in cueing: Groups A vs B vs C vs D.

Groups A, B, C and D differed in the type of cueing (verbal information before each sound) employed: Group A used name cueing (A : NC); B used the synthesizer's description (B : SDC); C used name cueing for the first five sessions and the synthesizer's description for the last five sessions (C : N/SDC); while D used name cueing supplemented with listeners' descriptions (D : NC - LDC). It is clear on inspection of Table 21 and Fig. 4 that Group B (SDC) was markedly superior to A, C and D. Group B differed from Groups A, C, and D in that the synthesizer's description was used as cueing A(BC), C(NC/SDC), and D(ND - LDC). The level of performance reached by Group B(SDC) over the last five sessions was reliably higher than that of all other groups and the saving in training time over other conditions was in the region of 40% to 50%. There were, however, no reliable differences in these respects between A(NC), C(NC/SDC), and D(NC-LDC).

Inspection of Fig. 4 and the accompanying equations shows that the only marked difference in rate of improvement over sessions was between B(SDC) and D(NC-LDC), B(SDC), showing 2.33% improvement per session compared with the 1.33% shown by D(NC-LDC). This difference is statistically significant ($t=2.4035$, $p < .05$).

On the first session the performance level of Group D (NC-LDC) was higher than that of Group A(NC) ($t=3.3919$, $p < .01$) and Group B(SDC). However, Group D(NC-LDC) did not show a statistically reliable improvement over sessions ($p=.388$), so that on the final sessions Group D(NC-LDC) merges with A(NC) and C(NC/SDC) and is well below the level achieved by B(SDC).

Group D(NC-LDC) is alone in failing to show a statistically reliable improvement over sessions.

2. The influence of item order: Group B vs E

In Group B the sounds on the training tape were in random order (B:R); in Group E each sound differed from the preceding item by one relevant quality, that is, the sounds were systematically and logically ordered (E:O*. Fig. 5 shows the plot of Group E (O) to be consistently superior to B (R) from the third session of training onward. The mean of the last five sessions for Group E (O) is 44.6% compared with 39.2% for Group B (R); this difference, which is statistically reliable ($t=2.5830$, $p < .05$) represents a saving in training time of 20%. The two groups do not differ reliably in terms of their relative improvements over sessions but Fig. 5 shows that Group E (O) may generalize to new items somewhat more readily than B (R).

3. The influence of high S/N ratios: Groups B vs F, and vs G

Group B was both trained and tested at realistic but difficult engine/cavitation (S/N) ratios (B:D,D): For the first five sessions Groups B, F, and G were treated identically in that all groups were both trained and tested on difficult items.

Comparisons between Groups B(D,D), F(V,D), and G(V,V) failed to yield any statistically reliable differences, although Group F(V,D) did show a small superiority over B(D,D) and G(V,V) (Fig. 6).

4. The influence of cueing vs knowledge of results: Group G vs H

For the first five sessions Groups G and H were treated identically. On the last five, Group G continued with the synthesizer's description as cueing (B:SDC) whereas Group H heard the synthesizer's description after (not before) the sound, that is, they had immediate knowledge of results (KR), (H:SDKR).

No significant differences were observed between Groups G (SDC) and H (SKDR), but H showed a small, non-significant superiority (Fig. 7).

5. The influence of using training items as test items

In Fig. 8 are plotted the proportions % correct items/% old items correct, as a function of sessions. Points below the horizontal line (drawn at 1.00) indicate that old items had the higher probability of being correctly identified and points above the horizontal indicate that new items are the better recognized. Of interest is the overall finding that new items are as likely to be answered correctly as old items. Since the inserted old items may have inadvertently been made more difficult (of lower S/N ratios) than the test items, it cannot be confidently concluded that subjects identify new items as easily as old. It can be concluded, however, that a sizable proportion of learning is of the general kind. Comparisons of the plots of Groups A, B, and D in Fig. 8 show some interesting but non-significant tendencies. Group B apparently tends to generalize to new items more readily than A or D, and Group A seems to improve in its ability to generalize as training proceeds.

DISCUSSION OF FINDINGS

In the following paragraphs we shall refer in turn to the questions posed on pages 5 to 8, state the conclusions which may be drawn from the experiments and translate the findings into practical recommendations to the programmer.

1. Should verbal descriptions be used?

Verbal labels used to describe the engine noise are effective if, and only if (a) they succeed in communicating to the trainee the actual parameters of the sound to which he must respond (B vs A, Fig. 4) and (b) the descriptions are used from the beginning of training (B vs C, Fig. 4). The descriptions supplied by experienced listeners were not as effective as descriptions of the actual parameters of the sounds (D vs B, Fig. 4). They yielded a high initial level of performance but failed to improve significantly with training. Listeners' labels may therefore function as "pointers" highlighting the sound from the noise and possibly indicating some of its characteristics. In any case, they were equally as effective as name cues only (D vs A, Fig. 4). They fail, however, to act as efficient aids to memory and are probably harmful in this respect.

The choice the programmer has to make is between supplying no labels in his program, supplying labels early in training and not encouraging dependence upon them later, or continuing with the existing use of labels. This choice will depend upon whether he considers that he is communicating the truthful facts about the sounds, i.e., whether the procedures adopted with Group B or Group D correspond the more closely to his procedures. It will be recalled that only the most valid of the listeners' descriptions were fed to Group D; thus the experimenter made every attempt to convert the listeners' descriptions into "synthesizers' descriptions" by rejecting all those which emphasized irrelevant or incorrect sound characteristics. Ostensibly this procedure may be considered to have produced labels <u>superior</u> to the descriptions used in the machine program, whose only redeeming characteristic is that they were coined by even more experienced listeners than our own subjects, who had received only 10 to 13 hours of exposure. Since the initially high levels of performance shown by Group B are of little practical significance, it is recommended that the machine program be run with and without descriptions so that more direct information may be gained about the status of the programmer's labels. The alternative is that labels be omitted from the program, since the evidence suggests that improvement is minimal under these conditions.

2. Is some advantage to be gained from reordering of items?

It was the purpose of the comparisons between Groups B and E to test the effectiveness of one type of ordering of items. The results showed that the particular order chosen was effective. Thus an order in which each item differs from the preceding item by one relevant quality was shown to be superior to a random order. The finding has both practical and theoretical significance. Practically, the finding suggests that sounds which the trainee is likely to find difficult to distinguish should be presented alternately, not separated in time or by other intervening sounds. In general, time spent by the programmer in reordering his items and any comparisons he makes between different orders is probably time well spent.

3. Should good recordings be used?

The present experiments have failed to demonstrate that a significant advantage is gained with the use of noise-free and high S/N recordings. Thus any advantage gained by being able to hear the relevant qualities of the sounds is offset to some extent by the trainer's unpreparedness for the low S/N ratio test recordings, or from his untrained capacity to listen to heavily masked signals. These findings indicate that there is little to be gained from being too selective in the choice of expensively acquired ship recordings. The finding also suggests that listening beneath noise may be a skill which can be improved beyond normal limits with training. It may thus be profitable to devote some proportion of training time to acquiring this skill.

4. Is cueing more effective than feedback?

Feedback procedures are usually used as motivational aids and as such they are perhaps best used at the end of a long period of training when motivation is probably at its lowest level. For this reason the feedback method was used during the latter half of the training program in the present experiment. The results showed a slight but non-significant superiority for the feedback condition over the cueing procedure. Sidley's findings which were referred to earlier, taken in conjunction with the present findings, would seem to indicate that it might prove beneficial to introduce a time-overlap feedback procedure in the latter stages of the program. Sidley's results alone would suggest that when the feedback procedure is necessary in the program the time-overlap procedure should be employed in order to get the most out of each training presentation.

5. Is specific recording or engine type learned?

The data (Fig. 8) indicate that type rather than specific recording was learned. This conclusion must be qualified with the reminder that there is no guarantee that the training items within the test tapes were of the same level of difficulty as the test items. Since a good deal of care was taken in the preparation of the tapes, this possibility is unlikely. The programmer may therefore feel confident that his index of attainment based partially upon "old" items does not seriously overestimate the trainee's real attainment.

CONCLUSIONS

The present report has led to the following conclusions:

1. Verbal descriptions that pertain to the actual physical characteristics of the sounds should be used. Those supplied by "experienced" listeners should be used with caution.

2. An advantage is likely to be gained by experimenting with the order in which training items are presented. The order found most useful in the present experiments involved the presentation of one change in a relevant quality per item.

3. Good recordings are not necessary, but there is certainly no disadvantage in their use.

4. Feedback procedures should be concentrated more at the end of a training program and recordings should be extended temporally to overlap with the feedback.

5. A large population of engine noises is probably desirable but not necessary.

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Table 1. Description of the relevant characteristics of Engine sounds and appropriate response categories.

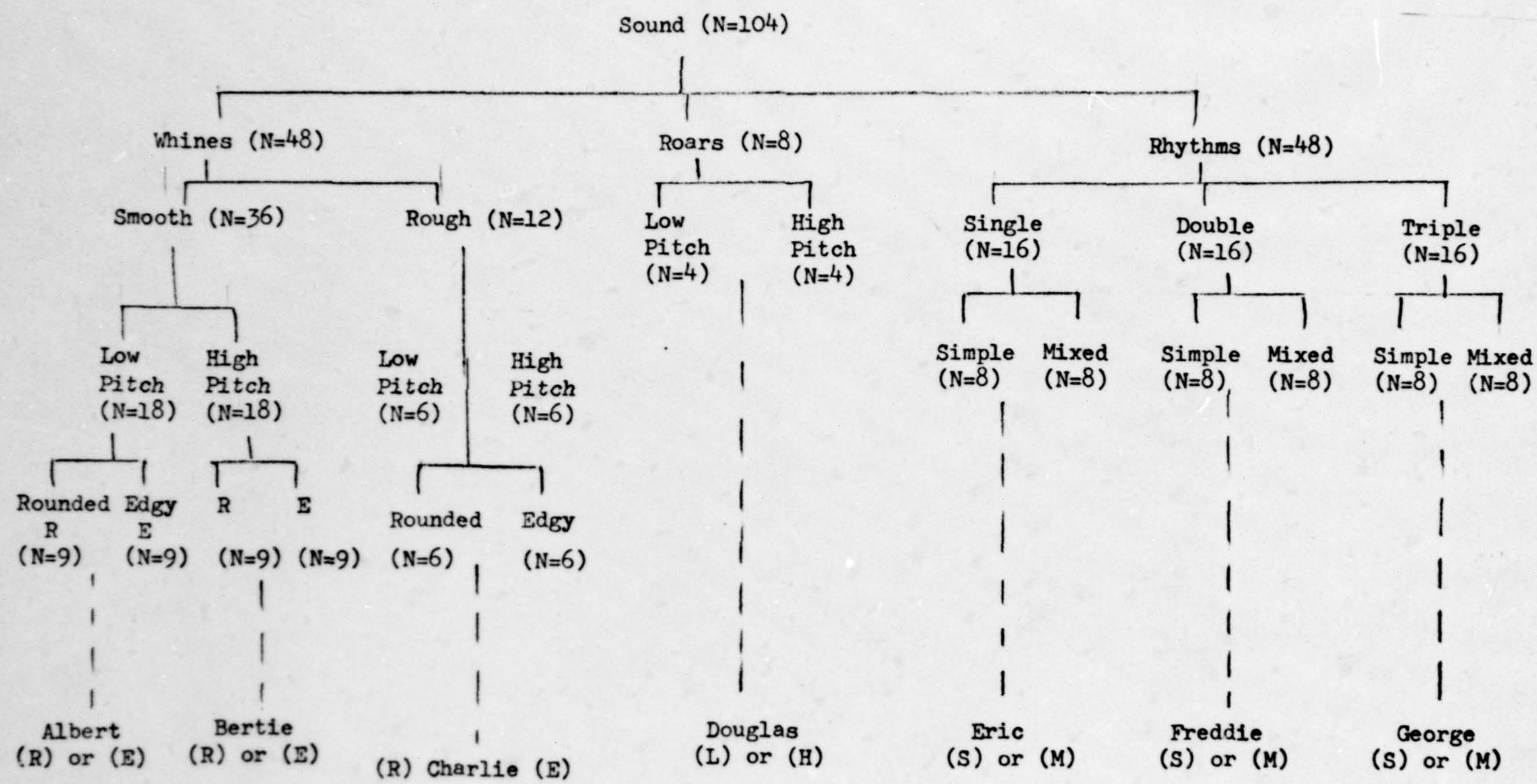

Table 2

Engine Sounds 1 to 48, Whines (Albert, Bertie, Charlie)

	Pitch: Low (Albert, if smooth) (Charlie, if rough)			Pitch: High (Bertie, if smooth) (Charlie, if rough)		
	82 cps	100 cps	125 cps	160 cps	205 cps	245 cps
Engine Sound	1	5	17	21	33	37
	2	6	18	22	34	38
	3	7	19	23	35	39
	4	8	20	24	36	40
	9	11	25	27	41	43
	10	12	26	28	42	44
	13	15	29	31	45	47
	14	16	30	32	46	48

	Smooth (Albert, if low; Bertie, if high): Unmodulated			Smooth: Freq. Modulated		Rough (Charlie): Amplit. & Freq. Mod.	
Engine Sound	1	17	33	13	31	9	27
	2	18	34	14	32	10	28
	3	19	35	15	45	11	41
	4	20	36	16	46	12	42
	5	21	37	29	47	25	43
	6	22	38	30	48	26	44
	7	23	39				
	8	24	40				

Band-Pass Filter Limits in cps

	Rounded (R): 40-450	40-600		225-1250	Edgy (E): 450-2500		320-5000	1250-5000
Engine Sound	1	9	27	2	10	28	3	4
	5	13	31	6	14	32	7	8
	17	11	41	18	12	42	19	20
	21	15	45	22	16	46	23	24
	33	25	43	34	26	44	35	36
	37	29	47	38	30	48	39	40

Note: The underlined engine numbers are those used in Training Tapes 1 through 5.

Table 3. Engine Sounds 49 to 56, Roars (Douglas)

Formant-filter peak in cps

Low (L) — High (H)

	120	140	160	180	200	220	240	300
Engine Sound	49	50	51	52	53	54	55	56

Table 4. Engine Sounds 57 to 104, Rhythms (Eric, Freddie, George)

	Rhythm Single (Eric)	Rhythm Double (Freddie)	Rhythm Triple (George)
Engine Sound	57 to 72	73 to 88	89 to 104

Harmonic Component(s) Present

	Simple (s)		Mixed (M)	
	5(288 cps)	10(575 cps)	2,4,5,6,8,10 115 to 575 cps	5,6,8,10 288 to 575 cps
Engine Sound	59 83	60 84	58 82	57 81
	63 87	64 88	62 86	61 85
	67 91	68 92	66 90	65 89
	71 95	72 96	70 94	69 93
	75 99	76 100	74 98	73 97
	79 103	80 104	78 102	77 101

Note: The underlined engine numbers are those used in Training Tapes 1 through 5.

Table 5. Order, Number, Description, Name, and S/N ratios for engine/cavitation sounds for Training Tapes 1 and 5a, b, c, d, and e

TRAINING TAPE 1 — TRAINING TAPE 5

ITEM NO.	ENGINE NO.	CAVITATION	S/N RATIO	DESCRIPTION*	NAME**	Relative level in dB of Engine above Cavitation Re levels used on TTI — Training Tapes 5. 5a	5b	5c	5d	5e	TT1
1.	54	Heavy (He)	-10	RrH	Douglas (H)	10	7	5	2	1	0
2.	20	Hard (Ha)	-50	WLSE	Albert (E)	50	35	20	10	3	0
3.	89	Light (L)	-38	RhTM	George (M)	38	28	18	8	2	0
4.	60	Medium (M)	-14	RhSSi	Eric (s)	14	9	6	3	1	0
5.	26	Compressed (C)	-48	WLRE	Charlie (E)	48	36	24	12	4	0
6.	55	L	-40	RrH	D (H)	40	30	20	10	3	0
7.	67	M	-30	RhSSi	E (s)	30	22	14	6	2	0
8.	86	M	-20	RhDM	F (M)	20	15	10	5	2	0
9.	37	L	-44	WHSRd	B (R)	44	33	22	11	3	0
10.	100	C	-40	RhTSr	G (s)	40	30	20	10	3	0
11.	79	L	-26	RhDSi	F (s)	26	18	12	6	2	0
12.	41	Ha	-42	WHRRd	C (R)	42	32	21	10	3	0
13.	13	He	-28	WLSRd	A (R)	28	20	13	6	2	0
14.	50	Ha	-14	RrL	D (L)	14	9	6	3	1	0
15.	36	He	-50	WHSE	B (E)	50	35	20	10	3	0
16.	48	M	-38	WHSE	B (E)	38	28	18	8	3	0
17.	11	C	-38	WLRRd	C (R)	38	28	18	8	3	0
18.	51	Ha	-10	RrL	D (L)	10	7	5	2	1	0
19.	102	C	-38	RhTM	G (M)	38	28	18	8	3	0
20.	95	M	-20	RhTSi	G (s)	20	15	10	5	2	0
21.	61	He	-38	RhSM	E (M)	38	28	18	8	3	0
22.	73	Ha	-42	RhDM	F (M)	42	32	21	10	3	0
23.	42	M	-38	WHRE	C (E)	38	28	18	8	2	0
24.	76	He	-38	RhDSi	F (s)	38	28	18	8	2	0
25.	14	C	-48	WLSE	A (E)	48	36	24	12	4	0
26.	29	L	-42	WLSRd	A (R)	42	32	21	10	3	0
27.	21	He	-30	WHSRd	B (R)	30	24	14	6	2	0
28.	70	C	-44	RhSM	E (M)	44	33	22	11	3	0

* W = Whine; L = Low pitch; H = High pitch; R = Rough; S = Smooth; Rd = Rounded; E = Edgy
Rr = Roar; H = High pitch; L = Low pitch
Rh = Rhythm; S = Single; D = Double; T = Triple; Si = Simple; M = Mixed

** A = Albert, B = Bertie, C = Charlie, D = Douglas, E = Eric, F = Freddie, G = George
(R) = Rounded, (E) = Edgy, (H) = High, (L) = Low, (s) = Simple, (M) = Mixed

Table 6. Training Tape 3 with revised non-random order (used with Group E)

The Cavitations and S/N ratios are identical with Training Tape 1, Table 2.

ORDER	ENGINE NO.	DESCRIPTION	NAME
1.	20	WLSE	A (E)
2.	29	WLSRd	A (R)
3.	11	WLRRd	C (R)
4.	41	WHRRd	C (R)
5.	21	WHSRd	B (R)
6.	48	WHSE	B (E)
7.	14	WLSE	A (E)
8.	13	WLSRd	A (R)
9.	37	WHSRd	B (R)
10.	36	WHSE	B (E)
11.	42	WHRE	C (E)
12.	26	WLRE	C (E)
13.	50	RrL	D (L)
14.	54	RrH	D (H)
15.	51	RrL	D (L)
16.	55	RrH	D (H)
17.	67	RhSSi	E (s)
18.	70	RhSM	E (M)
19.	73	RhDM	F (M)
20.	76	RhDSi	F (s)
21.	95	RhTSi	G (s)
22.	102	RhTM	G (M)
23.	61	RhSM	E (M)
24.	60	RhSSi	E (s)
25.	100	RhTSi	G (s)
26.	89	RhTM	G (M)
27.	86	RhDM	F (M)
28.	79	RhDSi	F (s)

Table 7. Test Tape i

	ENGINE	CAVITATION	DESCRIPTION	NAME	S/N
1.	8	He	WLSE	A (E)	-48
2.	39	C	WHSE	B (E)	-44
3.	53	M	RrH	D (H)	-16
4.	3	M	WLSE	A (E)	-34
5.	77	Ha	RhDM	F (M)	-32
•6.	86	M	RhDM	F (M)	-20
7.	87	M	RhDSi	F (s)	-16
8.	98	M	RhTM	G (M)	-18
9.	69	C	RhSM	E (M)	-28
10.	72	C	RhSSi	E (s)	-44
11.	56	M	RrH	D (H)	-14
12.	34	M	WHSRd	B (R)	-30
13.	17	Ha	WLSRd	A (R)	-30
14.	10	He	WLRE	C (E)	-46
15.	44	Ha	WHRE	C (E)	-50
16.	65	He	RhSM	E (M)	-30
17.	93	Ha	RhTM	G (M)	-30
•18.	11	C	WLRRd	C (R)	-38
19.	31	He	WHSRd	B (R)	-32
20.	63	C	RhSSi	E (s)	-36
21.	84	L	RhDSi	F (s)	-36
22.	103	C	RhTSi	G (s)	-32
23.	96	Ha	RhTSi	G (s)	-38
24.	52	L	RrL	D (L)	-24
25.	49	He	RrL	D (L)	-10
26.	45	L	WHSRd	B (R)	-38
•27.	36	He	WHSE	B (E)	-50
28.	1	L	WLSRd	A (R)	-34

•These items are injected "training" items.

Table 8. Test Tape ii and S/N ratios for Test Tape iia.

TEST TAPE ii

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N	S/N ratios for iia
1.	52	Ha	RrL	D (L)	-10	-2
2.	81	M	RhDM	F (M)	-20	-5
3.	32	M	WHSE	B (E)	-38	-10
4.	9	L	WLRRd	C (R)	-30	-8
5.	50	M	RrL	D (L)	-14	-5
*6.	89	L	RhTM	G (M)	-38	-10
7.	88	C	RhDSi	F (s)	-42	-10
8.	18	He	WLSRd	A (R)	-40	-10
9.	28	C	WHRE	C (E)	-44	-10
10.	56	C	RrH	D (H)	-32	-8
11.	42	Ha	WHRE	C (E)	-54	-20
*12.	13	He	WLSRd	A (R)	-28	-8
13.	25	C	WLRRd	C (R)	-38	-10
14.	62	L	RhSM	E (M)	-36	-10
*15.	67	M	RhSSi	E (s)	-30	-8
16.	101	He	RhTM	G (M)	-32	-12
*17.	54	He	RrH	D (H)	-10	-2
18.	33	L	WHSRd	B (R)	-36	-10
19.	59	Ha	RhSSi	E (s)	-22	-5
20.	75	C	RhDSi	F (s)	-40	-12
21.	92	M	RhTSi	G (s)	-18	-5
22.	104	L	RhTSi	G (s)	-36	-10
23.	82	L	RhDM	F (M)	-40	-10
24.	57	He	RhSM	E (M)	-34	-8
25.	40	He	WHSE	B (E)	-52	-15
26.	30	He	WLSE	A (E)	-50	-15
27.	22	Ha	WHSRd	B (R)	-48	-12
28.	4	M	WLSE	A (E)	-40	-12

*Found also in training tape.

Table 9. Test Tape iii and S/N Ratios for Tape iiia

TEST TAPE iii

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N	S/N Ratios for iiia
1.	16	L	WLSE	A (E)	-38	-20
2.	49	Ha	RrL	D (L)	-10	-5
3.	68	Ha	RhSSi	E (s)	-38	-20
4.	91	L	RhTSi	G (s)	-30	-16
•5.	37	L	WHSRd	B (R)	-44	-22
6.	99	He	RhTSi	G (s)	-28	-15
7.	43	L	WHRRd	C (R)	-40	-20
8.	6	He	WLSRd	A (R)	-50	-30
9.	23	Ha	WHSE	B (E)	-50	-30
10.	55	He	RrH	D (H)	-10	-5
11.	66	L	RhSM	E (M)	-38	-20
12.	83	He	RhDSi	F (s)	-22	-12
13.	74	M	RhDM	F (M)	-18	-10
14.	51	L	RrL	D (L)	-26	-14
15.	5	M	WLSRd	A (R)	-28	-15
16.	12	Ha	WLRE	C (E)	-50	-30
17.	47	M	WHSRd	B (R)	-22	-11
18.	94	M	RhTM	G (M)	-16	-10
19.	90	Ha	RhTM	G (M)	-40	-20
20.	78	C	RhDM	F (M)	-36	-18
21.	64	C	RhSSi	E (s)	-44	-22
22.	53	He	RrH	D (H)	-10	-5
23.	7	M	WLSE	A (E)	-34	-17
•24.	26	C	WLRE	C (E)	-48	-24
25.	27	C	WHRRd	C (R)	-40	-20
26.	58	C	RhSM	E (M)	-44	-22
27.	24	C	WHSE	B (E)	-48	-24
•28.	79	L	RhDSi	F (s)	-26	-13

Table 10. Test Tape iv and S/N ratios for Test Tape iva

TEST TAPE iv

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N	S/N Ratios for iva
*1.	95	M	RhTS	G (s)	-20	-15
2.	81	He	RhDM	F (M)	-30	-24
*3.	51	Ha	RrL	D (L)	-10	-8
4.	33	He	WHSRd	B (R)	-40	-30
5.	9	C	WLRRd	C (R)	-38	-30
6.	1	M	WLSRd	A (R)	-20	-15
7.	28	He	WHRE	C (E)	-46	-35
8.	38	Ha	WHSRd	B (R)	-50	-40
9.	68	He	RhSSi	E (s)	-38	-30
10.	71	M	RhSSi	E (s)	-26	-20
11.	87	C	RhDSi	F (s)	-36	-28
12.	80	C	RhDSi	F (s)	-30	-24
13.	103	M	RhTSi	G (s)	-18	-14
14.	56	L	RrH	D (H)	-32	-26
*15.	14	C	WLSE	A (E)	-48	-36
16.	25	Ha	WLRRd	C (R)	-42	-32
17.	49	C	RrL	D (L)	-28	-22
18.	46	L	WHSE	B (E)	-44	-33
19.	69	L	RhSM	E (M)	-34	-26
20.	85	L	RhDM	F (M)	-32	-26
21.	93	C	RhTM	G (M)	-32	-26
22.	97	He	RhTM	G (M)	-28	-22
*23.	61	He	RhSM	E (M)	-38	-30
24.	54	Ha	RrH	D (H)	-12	-9
25.	44	L	WHRE	C (E)	-46	-34
26.	35	M	WHSE	B (E)	-34	-26
27.	19	L	WLSE	A (E)	-38	-30
28.	15	Ha	WLSRd	A (R)	-36	-28

Table 11. Test Tape v and S/N ratios for Test Tape va

TEST TAPE v

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N	S/N Ratios for va
1.	27	He	WHRRd	C (R)	-26	-24
2.	22	L	WHSRd	B (R)	-38	-35
3.	50	L	RrL	D (L)	-22	-20
4.	98	Ha	RhTM	G (M)	-34	-32
5.	73	L	RhDM	R (M)	-32	-30
•6.	60	M	RhSSi	E (s)	-14	-12
7.	10	H	WLRE	C (E)	-50	-46
•8.	42	M	WHRE	C (E)	-38	-36
•9.	70	C	RhSM	E (M)	-44	-40
10.	96	L	RhTSi	G (s)	-30	-28
11.	77	L	RhDM	F (M)	-26	-24
12.	23	L	WHSE	B (E)	-42	-38
13.	8	M	WLSE	A (E)	-36	-33
14.	7	He	WLSE	A (E)	-46	-42
15.	2	M	WLSR	A (R)	-28	-26
16.	52	C	RrL	D (L)	-24	-22
17.	62	He	RhSM	E (M)	-38	-35
18.	80	M	RhDSi	F (s)	-18	-16
19.	90	He	RhTM	G (M)	-32	-30
20.	104	Ha	RhTSi	G (s)	-36	-33
21.	55	M	RrH	D (H)	-22	-20
22.	5	C	WLSRd	A (R)	-40	-37
23.	34	He	WHSRd	B (R)	-44	-40
•24.	41	Ha	WHRRd	C (R)	-42	-38
25.	83	Ha	RhDSi	F (s)	-24	-22
26.	57	C	RhSM	E (M)	-42	-38
27.	53	Ha	RrH	L (H)	-10	-9
28.	35	C	WHSE	B (E)	-44	-40

Table 12. Test Tape vi

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N
1.	17	M	WLSRd	A (R)	-26
2.	40	L	WHSE	B (E)	-44
3.	58	Ha	RhSM	E (M)	-40
4.	74	L	RhDM	F (M)	-34
5.	78	He	RhDM	F (M)	-26
6.	97	M	RhTM	G (M)	-18
7.	91	He	RhTSi	G (s)	-24
8.	84	C	RhDSi	F (s)	-42
9.	38	C	WHSRd	B (R)	-42
10.	6	Ha	WLSRd	A (R)	-46
11.	50	C	RrL	D (L)	-20
12.	43	He	WHRRd	C (R)	-34
•13.	21	He	WHSRd	B (R)	-30
•14.	102	C	RhTM	G (M)	-38
15.	3	C	WLSE	A (E)	-44
16.	12	C	WLRE	C (E)	-46
•17.	48	M	WHSE	B (E)	-36
18.	54	L	RrH	D (H)	-28
19.	100	M	RhTSi	G (s)	-22
20.	63	Ha	RhSSi	E (s)	-24
21	9	He	WLRRd	C (R)	-34
22.	19	Ha	WLSE	A (E)	-50
23.	44	M	WHRE	C (E)	-38
24.	52	M	RrL	D (L)	-12
25.	56	He	RrH	D (H)	-12
26.	59	L	RhSSi	E (s)	-28
27.	65	L	RhSM	E (M)	-34
28.	88	Ha	RhDSi	F (s)	-40

Table 13. Test Tape vii

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N
1.	69	Ha	RhSM	E (M)	-44
2.	18	C	WLSRd	A (R)	-42
3.	41	L	WHRRd	C (R)	-40
*4.	100	C	RhTSi	G (S)	-40
5.	85	He	RhDM	F (M)	-28
*6.	20	Ha	WLSE	A (E)	-50
7.	55	Ha	RrH	D (H)	-10
8.	4	He	WLSE	A (E)	-50
9.	64	He	RhSSi	E (s)	-40
*10.	76	He	RhDSi	F (s)	-38
11.	45	M	WHSRd	B (R)	-22
12.	92	Ha	RhTSi	G (s)	-42
*13.	50	Ha	RrL	D (L)	-14
14.	25	He	WLRRd	C (R)	-30
15.	24	L	WHSE	B (E)	-46
16.	82	C	RhDM	F (M)	-42
17.	66	M	RhSM	E (M)	-20
18.	31	M	WHSRd	B (R)	-20
19.	10	C	WLRE	C (E)	-46
20.	53	L	RrH	D (H)	-28
21.	75	L	RhDSi	F (s)	-32
22.	51	C	RrL	D (L)	-26
23.	94	L	RhTM	G (M)	-32
24.	101	C	RhTM	G (M)	-38
25.	32	Ha	WHSE	B (E)	-50
26.	15	M	WLSRd	A (R)	-20
27.	26	M	WLRE	C (E)	-18
28.	68	M	RhSSi	E (s)	-18

Table 14. Test Tape viii

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N
1.	84	M	RhDSi	F (s)	-16
2.	46	M	WHSE	B (E)	-38
3.	11	M	WLRRd	C (R)	-14
4.	27	M	WHRRd	C (R)	-20
5.	82	He	RhDm	F (M)	-36
6.	104	He	RhTSi	G (s)	-34
7.	49	L	RrL	D (L)	-20
8.	5	Ha	WLSRd	A (R)	-32
9.	28	L	WHRE	C (E)	-44
10.	53	C	RrH	D (H)	-28
11.	66	C	RhSM	E (M)	-44
•12.	73	Ha	RhDM	F (M)	-42
13.	51	He	RrL	D (L)	-10
14.	16	Ha	WLSE	A (E)	-50
15.	76	M	RhDSi	F (s)	-22
16.	92	He	RhTSi	G (s)	-34
17.	34	C	WHSRd	B (R)	-40
18.	12	He	WLRE	C (E)	-48
19.	71	He	RhSSi	E (s)	-24
20.	97	C	RhTM	G (M)	-36
21.	61	Ha	RhSM	E (M)	-36
22.	30	L	WLSE	A (E)	-46
23.	47	C	WHSRd	B (R)	-40
24.	89	Ha	RhTM	G (M)	-34
25.	39	Ha	WHSE	B (E)	-50
26.	72	L	RhSSi	E (s)	-40
•27.	29	L	WLSRd	A (R)	-42
•28.	55	L	RrH	D (H)	-40

Table 15. Test Tape ix

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N
1.	26	He	WLRE	C (E)	-50
2.	43	Ha	WHRRd	C (R)	-40
3.	93	He	RhTM	G (M)	-32
•4.	79	L	RhDSi	F (s)	-26
5.	16	C	WLSE	A (E)	-42
6.	38	He	WHSRd	B (R)	-44
7.	56	Ha	RrH	D (H)	-20
8.	91	C	RHTSi	S (s)	-40
9.	2	L	WLSRd	A (R)	-36
10.	52	He	RrL	D (L)	-10
11.	72	M	RhSSi	E (s)	-18
12.	101	L	RhTM	G (M)	-36
13.	23	M	WHSE	B (E)	-34
14.	31	C	WHSRd	B (R)	-42
15.	75	M	RhDSi	F (s)	-24
16.	62	C	RhSM	E (M)	-42
17.	7	Ha	WLSE	A (E)	-50
18.	67	L	RhSSi	E (s)	-36
19.	99	Ha	RhTSi	G (s)	-22
•20.	11	C	WLRRd	C (R)	-38
21.	18	L	WLSRd	A (R)	-36
22.	70	Ha	RhSM	E (M)	-40
23.	82	M	RhDM	F (M)	-16
24.	74	C	RhDM	F (M)	-40
25.	36	L	WMSE	B (E)	-44
26.	44	He	WHRE	C (E)	-50
27.	49	M	RrL	D (L)	-14
•28.	54	He	RrH	D (M)	-10

Table 16. Test Tape x

	ENGINE NO.	CAVITATION	DESCRIPTION	NAME	S/N
1.	78	Ha	RhDM	F (M)	-38
2.	50	C	RhTM	G (M)	-40
3.	28	Ha	WHRE	C (E)	-50
*4.	14	Ha	WLSE	A (E)	-48
5.	54	M	RrH	D (H)	-16
6.	68	C	RhSSi	E (s)	-44
*7.	76	He	RhDSi	F (s)	-38
8.	96	M	RhTSi	G (s)	-20
9.	21	M	WHSRd	B (R)	-18
*10.	48	M	WHSE	B (E)	-38
11.	86	He	RhDM	F (M)	-34
12.	56	L	RrH	D (H)	-32
13.	88	L	RhDSi	F (s)	-18
14.	102	M	RhTM	G (M)	-32
15.	1	L	WLSRd	A (R)	-40
16.	17	C	WLSRd	A (R)	-36
17.	60	L	RhSSi	E (s)	-40
18.	103	He	RhTSi	G (s)	-24
19.	69	He	RhSM	E (M)	-38
20.	27	He	WHRRd	C (R)	-36
21.	58	L	RhSM	E (M)	-36
22.	52	C	RrL	D (L)	-26
23.	30	Ha	WLSE	A (E)	-50
24.	42	L	WHRE	C (E)	-46
*25.	41	Ha	WHRRd	C (R)	-42
26.	49	Ha	RrL	D (L)	-10
27.	32	C	WHSE	B (E)	-50
28.	37	M	WHSRd	B (R)	-34

Table 17. Summary of the Varying Characteristics of Training Tapes 1 to 5 and Test Tapes i to x including Test Tapes ia to va

Number of tape	Type of Cueing (before the item)	Knowledge of Results (KR) (after the item)	Order of Sounds	Signal-to-Noise Ratio (S/N)
Trng T 1 (NC, -, R, D)	Name of sound only, i.e., Charlie E, etc.	None	Random	Difficult
Trng T 2 (SDC, -, R, D)	Synthesizer's Description, i.e., high pitched, edgy, etc.	None	Random	Difficult
Trng T 3 (SDC, -, O, D) as TT2 except for Order	Synthesizer's Description	None	Ordered Each sound differed from predecessor by one relevant characteristic	Difficult
Trng Ts 4 (-, SDKR, R, D) as TT2 except Synthesizer's Description after each item	None	Synthesizer's Description	Random	Difficult
Trng Ts 5 (SDC, -, R, V) as TT2 except for S/N ratios	Synthesizer's Description	None	Random	Varying Trng T 5a - no cavitation Trng T 5b to TT 5e more and more cavitation noise but never as much as on TTs 1 thru 4
TsT i to TsT x	None	None	Random. 3 or 4 items from Trng Tapes, others equally difficult	Difficult
TsTia to TsT va (as TsTs i to x except for S/N ratio)	None	None	Random	Tst ia - no cavitation TsTs iia to va - more and more cavitation noise like Trng Ts 5

Table 18. Allocation of Experimental Groups to Test and Training Tapes

Experimental Group	Test Session	Training Tape*	Additional Training Aids	Test Tapes	Control Group
A n = 12	1 to 10	1 NC, -, R, D	None	i to x	B
B n = 11	1 to 10	2 SDC, -, R, D	Physical description of sounds. Decision Rules and Table 19	i to x	A
C	1 to 5	1 NC, -, R, D	As A	i to x	A
n = 6	6 to 10	2 SDC, -, R, D	As B	i to x	B
D n = 12	1 to 10	1 NC, -, R, D	Listener's description of sounds See Table 20	i to x	A & B
E n = 11	1 to 10	3 SDC, -, O, D	As B	i to x	B
F	1 to 5	5 SDC, -, R, V	As B, plus explanation that S/N would go easy-hard	i to x	B
n = 5	6 to 10	2 SDC, -, R, D	As B	i to x	G
G	1 to 5	5 SDC, -, R, V	As F	ia to va	B, F
n = 12	6 to 10	2 SDC, -, R, D	As F	vi to x	B, H
H	1 to 5	5 SDC, -, R, V	As F	ia to va	G
n = 12	1 to 6	4 -, SDKR, O, D	Requested to make early response before (KR)	vi to x	G

*Definition Symbols in training tape column

NC = Name Cueing
SDC = Synthesizer's Description Cueing
SKDR = Synthesizer's Description Knowledge of Results
R = Random Order
O = Ordered Order
D = Difficult S/N
V = Varying S/N

Table 19. Copy of the classification given to Subjects in Groups B, E, F, G and H in conjunction with synthesizer's description

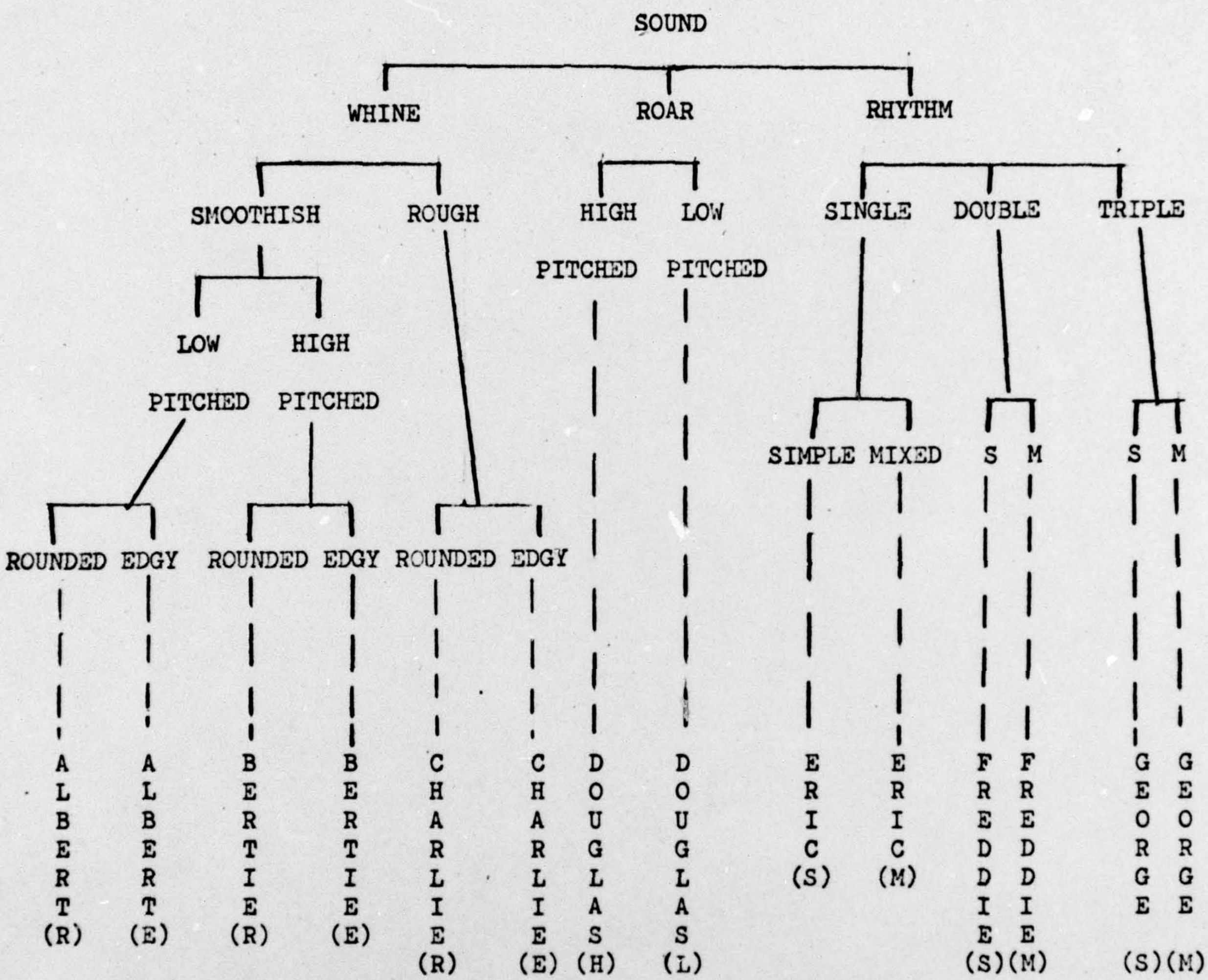

Table 20. Listeners' descriptions

Albert R	Soft, deep whine; a low buzz, a drone.
Albert E	Low gritty buzz; a wasp, an electric razor.
Bertie R	Medium soft motor whine; humming; a smooth buzz; high hum.
Bertie E	A fast high buzz; a fly or insect noise.
Charlie R	A watery buzz; the hum of a M.T.B.
Charlie E	Electric crackle; electric razor.
Douglas H	A high wind.
Douglas L	Waterfall; engine room.
Eric S	Sonar echo; steady regular blips.
Eric M	Owl in the distance; windscreen wipers.
Freddie S	Regular blips in two's; heartbeat timing.
Freddie M	Blipping hum, bongo drums.
George S	Train tones in three's, 1, 12
George M	Three bleeps; Morse.

Table 21. % Correct over the last 5 sessions, t and p values and % Saving in Training Time for Groups A, B, C and D

Group	% Correct	A	B	C	D
A	28.6%		50%	7%	15%
B	39.2%	t=5.2980 $p < .01$		-42%*	-40%*
C	31.0%	t=0.9564 N.S.	t=3.0051 $p < .01$		5%
D	32.6%	t=1.6445 N.S.	t=3.1442 $p < .01$	t=0.4397 N.S.	

* The negative (-) sign indicates that B is better than C and D so in summary there is a saving in time of training for B over A (50%), B over C (42%), and B over D (40%).

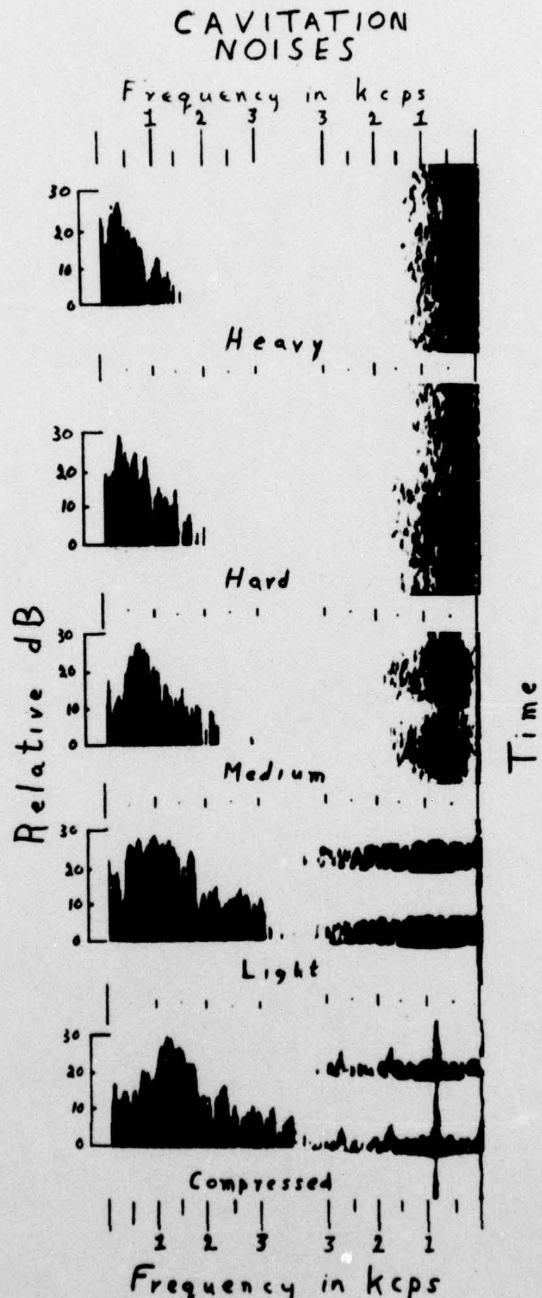
CAVITATION
NOISES
Frequency in kcps
1 2 3 3 2 1
30
20
10
0
Heavy
Hard
Medium
Light
Compressed
Relative dB
Time
1 2 3 3 2 1
Frequency in kcps

Fig 1

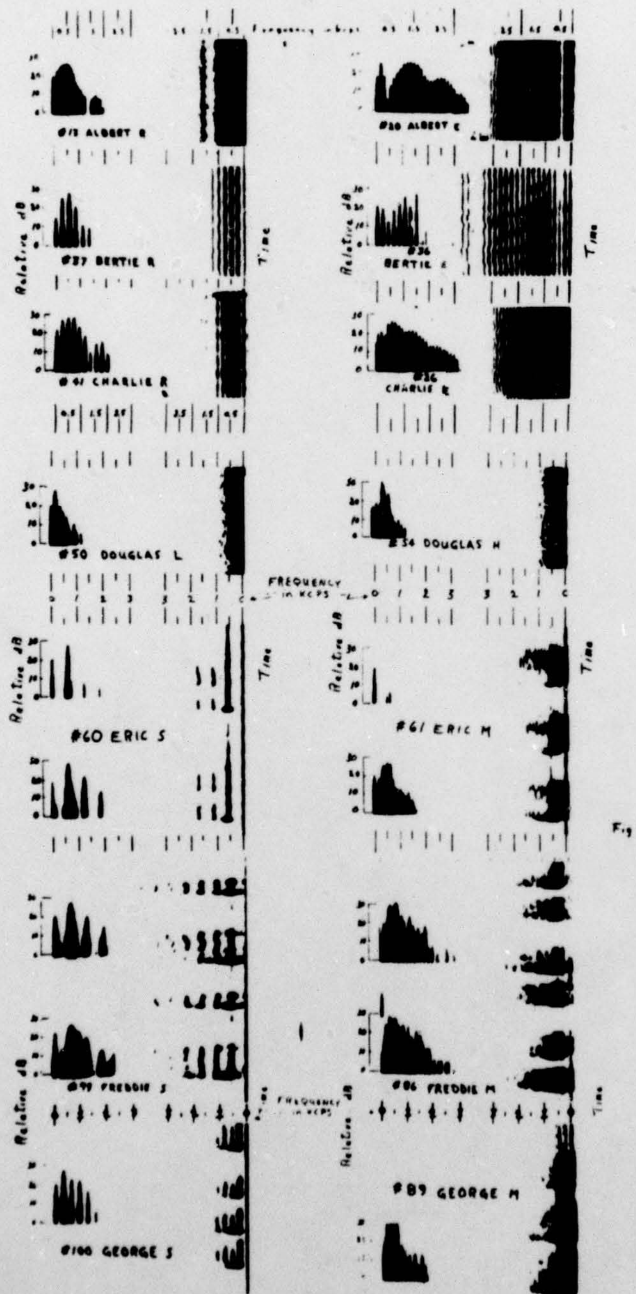
ALBERT R
ALBERT C
BERTIE R
BERTIE C
CHARLIE R
CHARLIE C
#50 DOUGLAS L
#54 DOUGLAS H
FREQUENCY IN KCPS
Time
Relative dB
#60 ERIC S
#61 ERIC M
FREDDIE S
#86 FREDDIE M
#89 GEORGE M
#100 GEORGE S

Fig 2

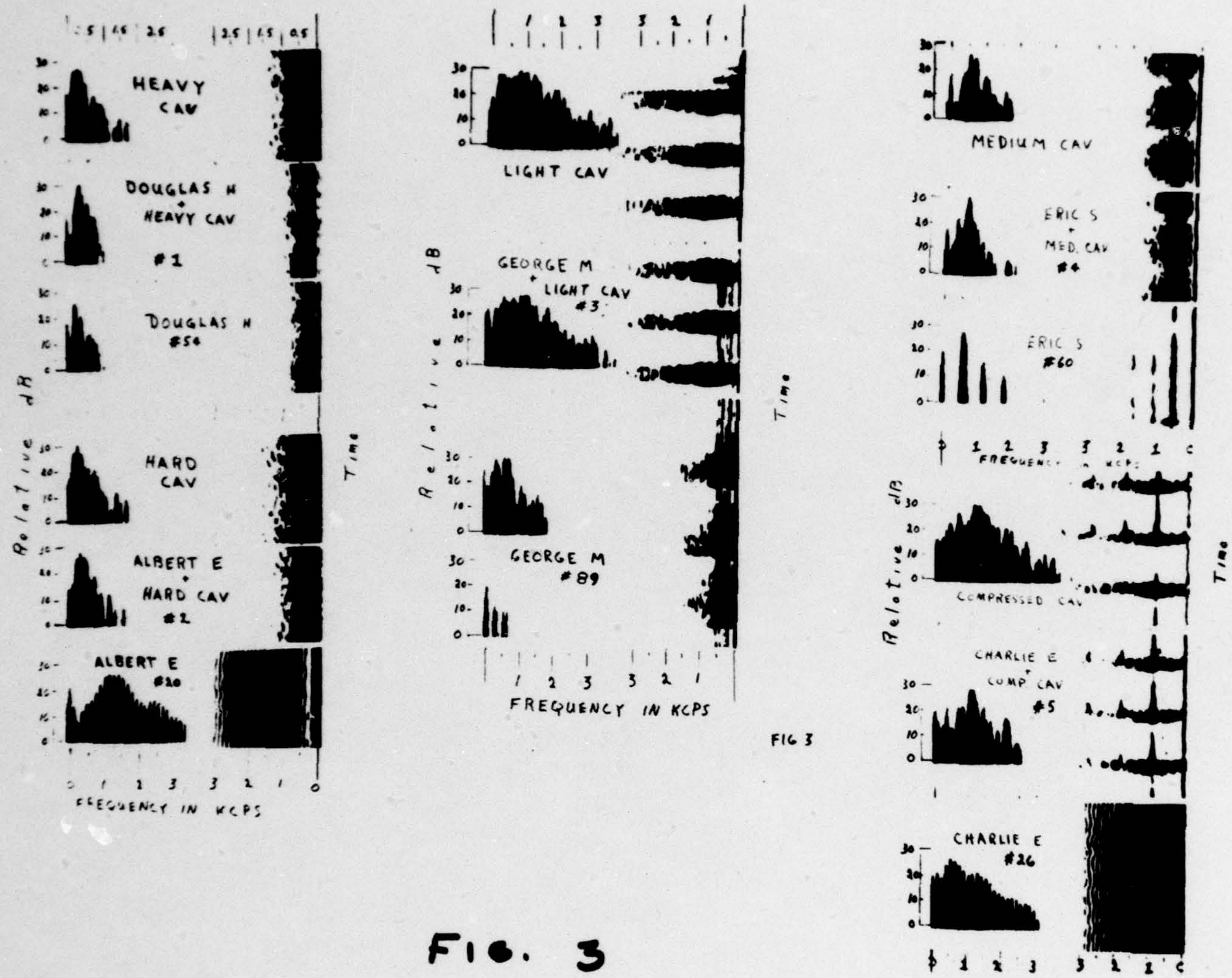
HEAVY CAV
DOUGLAS H + HEAVY CAV #1
DOUGLAS H #54
HARD CAV
ALBERT E + HARD CAV #2
ALBERT E #20
FREQUENCY IN KCPS
Relative dB
Time
LIGHT CAV
GEORGE M + LIGHT CAV #3
GEORGE M #89
FREQUENCY IN KCPS
Relative dB
Time
MEDIUM CAV
ERIC S + MED. CAV #4
ERIC S #60
COMPRESSED CAV
CHARLIE E + COMP CAV #5
CHARLIE E #26
Relative dB
Time
FIG 3

FIG. 3

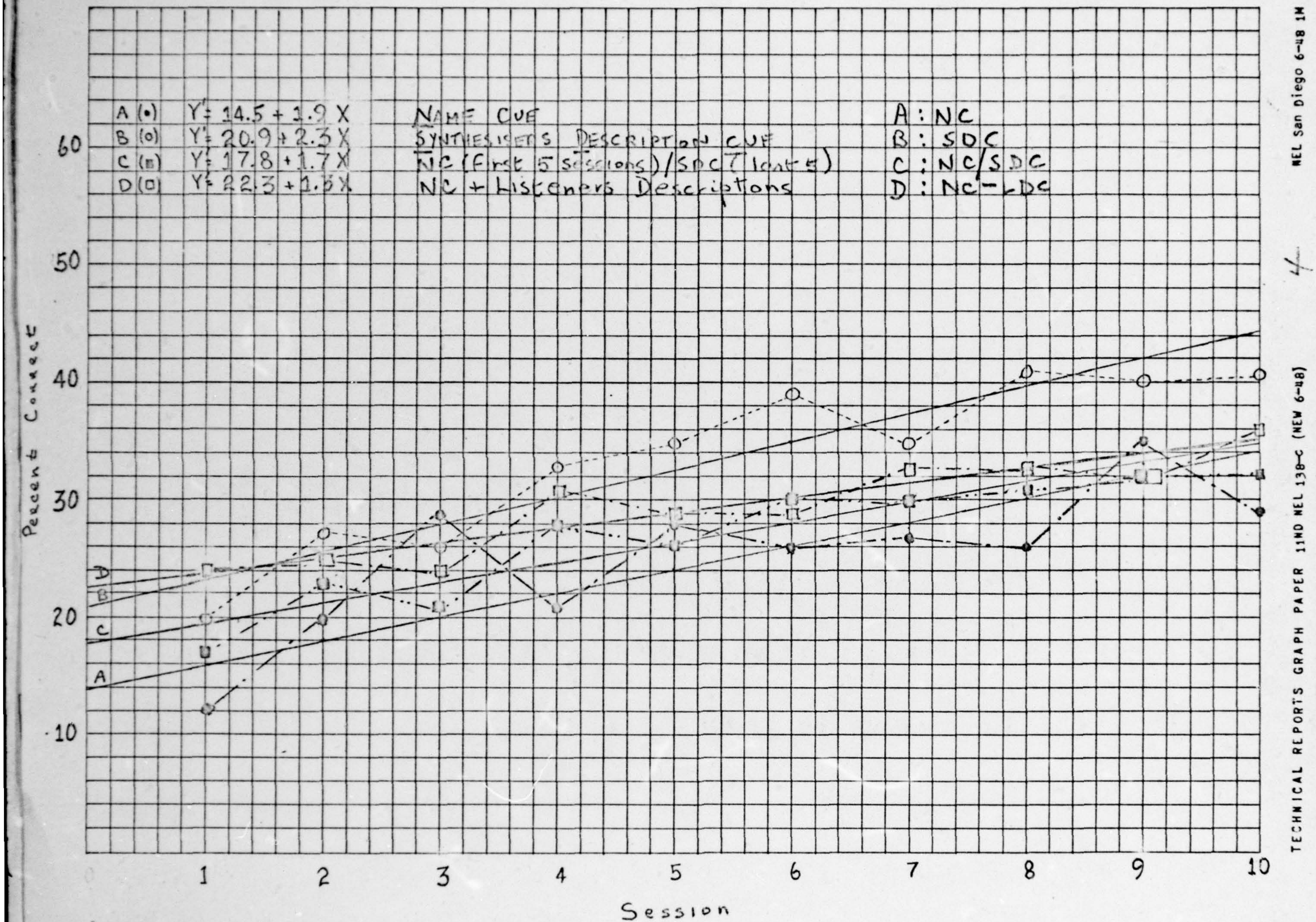

Fig. 4. Groups A, B, C, and D

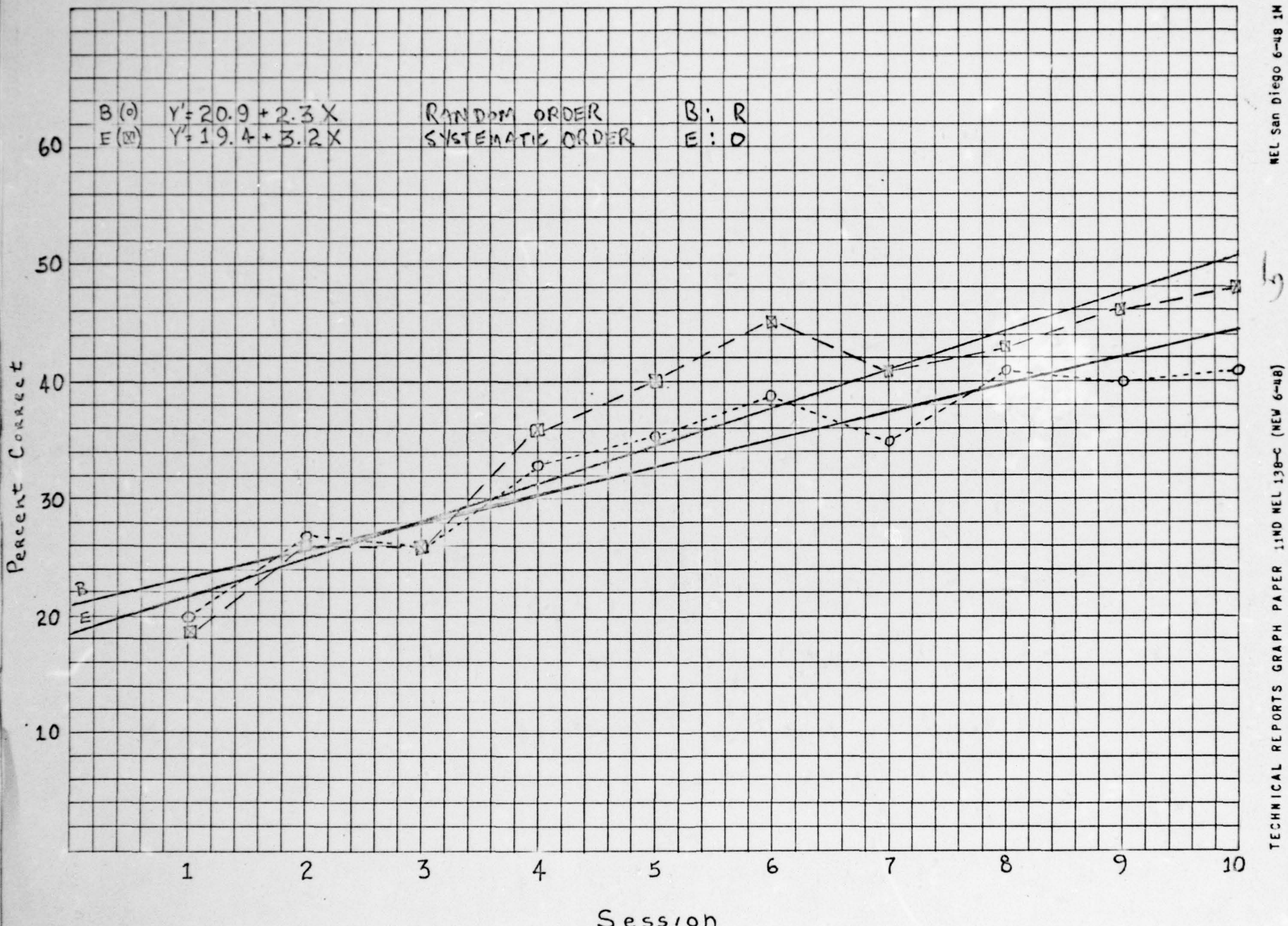

Fig. 5. Groups B and E

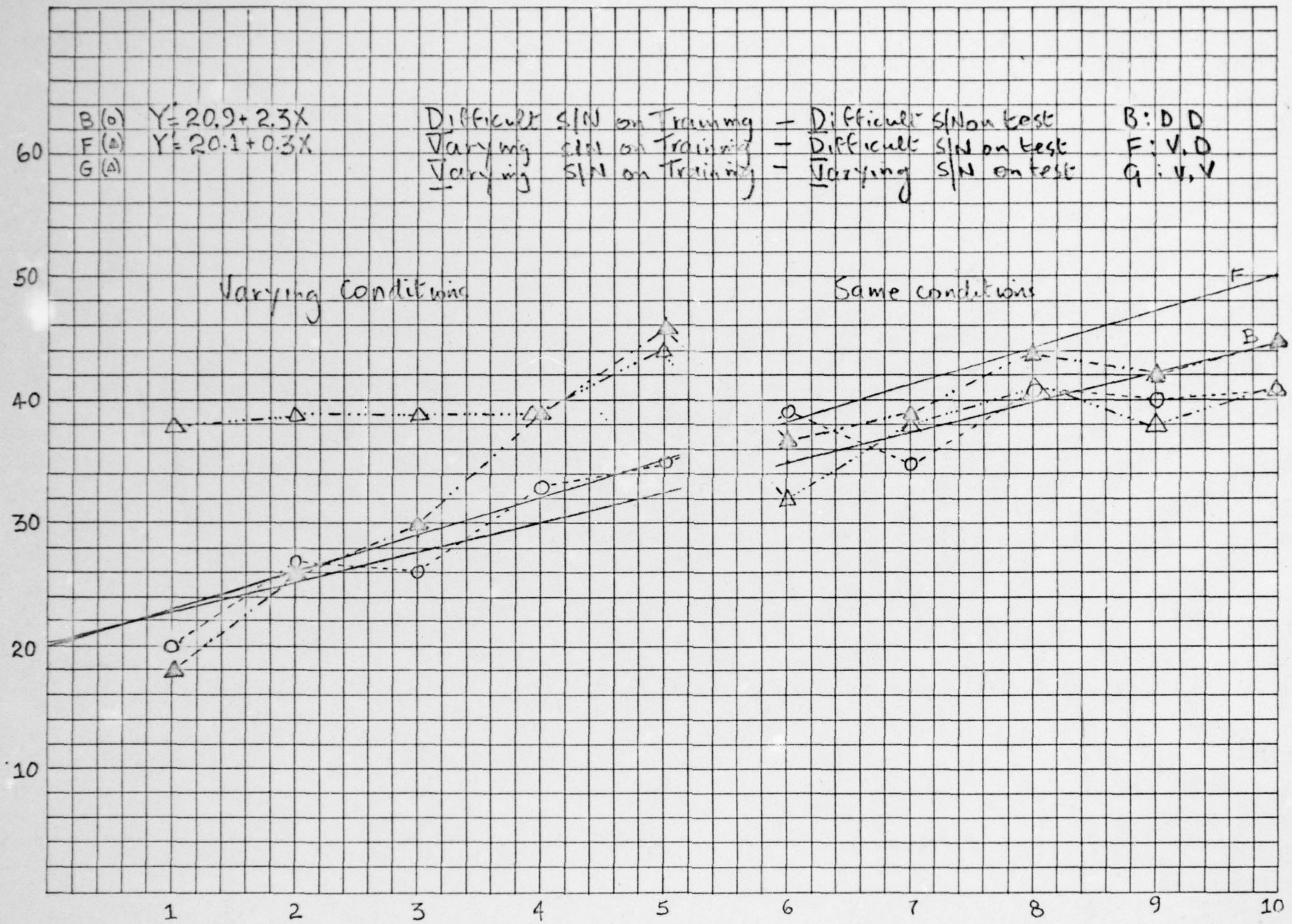

Fig. 6 Groups B, F, and G

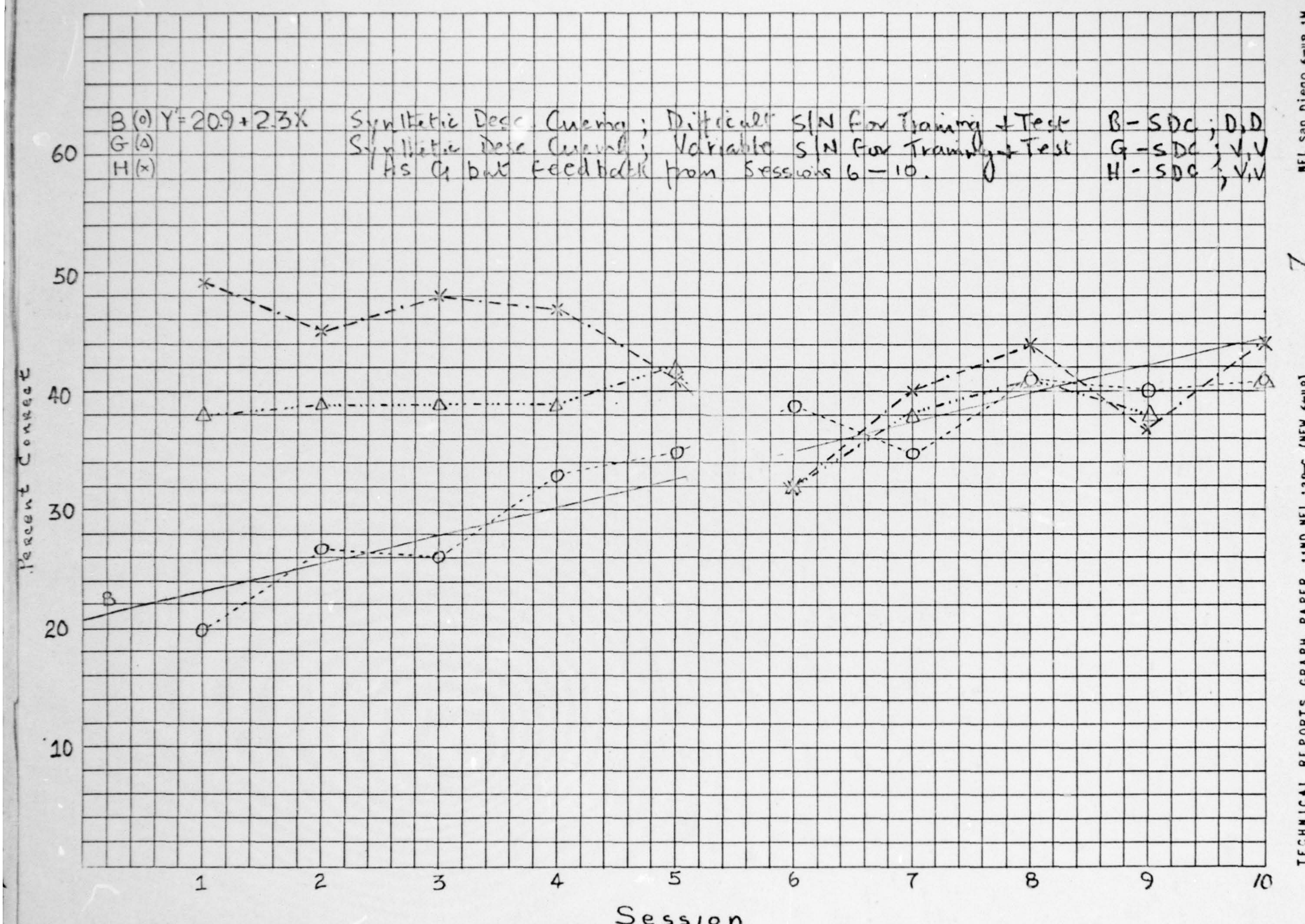

Fig. 7. Groups B, G, and H

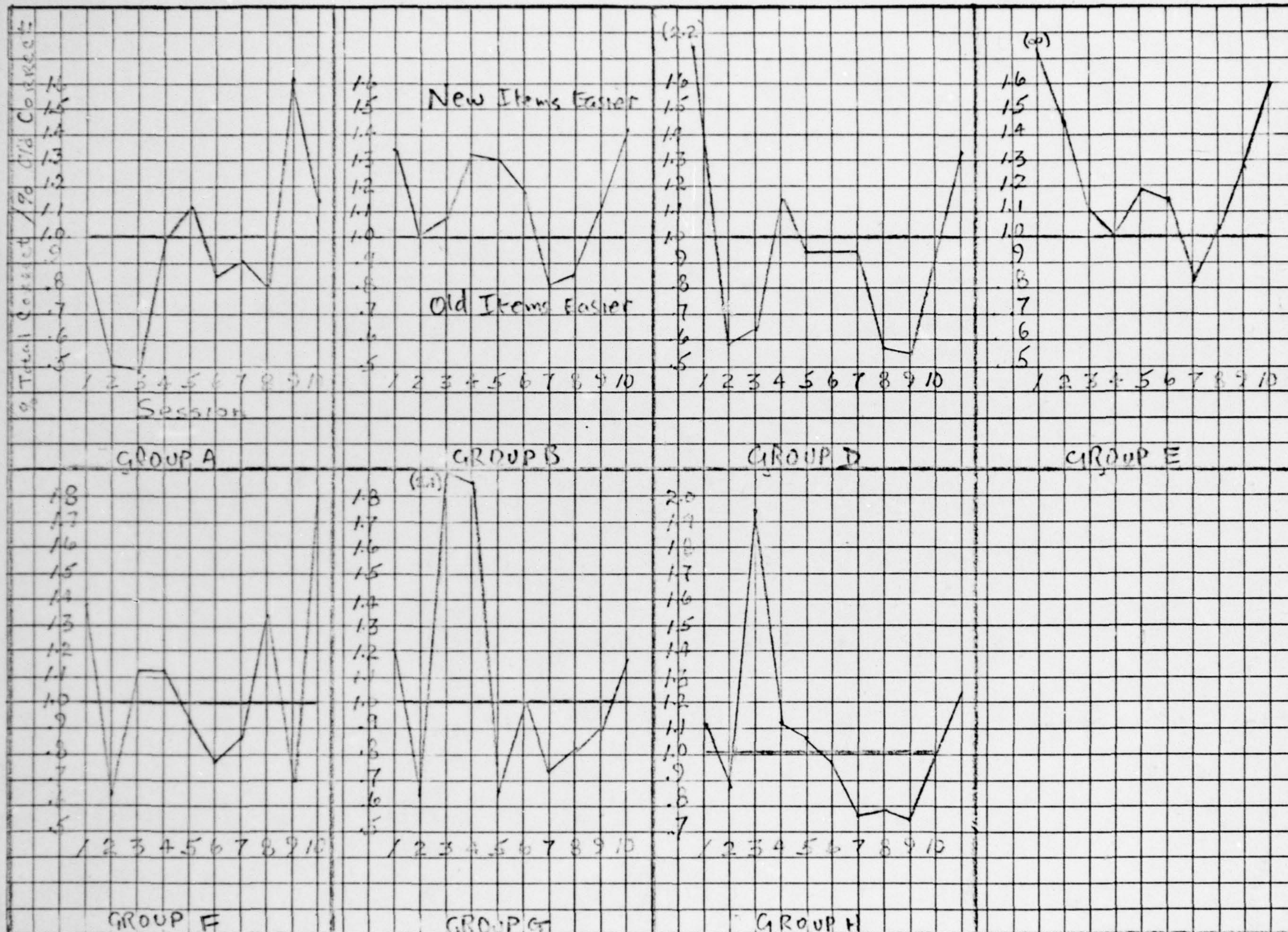
% Total Correct / % Old Correct
Session
New Items Easier
Old Items Easier
GROUP A
GROUP B
GROUP D
GROUP E
GROUP F
GROUP G
GROUP H

FIG. 8.

TM-1048

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