A FACTORIAL STUDY OF THE MEANING OF COMPLEX AUDITORY STIMULI (PASSIVE SONAR SOUNDS)

BY

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I. INTRODUCTION

This study represents the convergence of three disparate areas of investigation in an attempt to analyze one of the many problems encountered in the study of human factors in undersea warfare. The domains referred to are these: naval sonar, the nature of "meaning," and multidimensional scaling techniques. The problem may be stated as follows: In the detection and recognition of underwater sounds by the use of sonar equipment, what are the discriminative cues employed by the sonar operator? More generally, what factors does the operator utilize in decoding the significance of sonar signals?

By way of orientation, the following topics will be discussed in turn: (1) the nature of sonar and of the auditory stimuli it provides; (2) how the problem of the nature and measurement of psychological "meaning" enters into our investigation; and finally, (3) an historical survey of the methodological approaches to the study of "meaning" and how, at the present time, multidimensional scaling techniques and factor analysis appear to be meeting the need for objective methodology.

A. Naval Sonar

The nature of sonar and of the auditory stimuli it provides is best described by Neff and Thurlow (12, pp. 219-220):

> "Sonar makes use of sound waves which are transmitted readily through water; it picks up the sound signals from the water, amplifies them, and analyzes them in various ways so as to present to the operator of sonar equipment useful items of information about objects and their movement in the sea around him . . . Listening systems /passive sonar/ make use of the sounds emitted by objects in the water, e.g., the cavitation noise produced by the screws of a ship . . .

> "The operator of sonar listening gear needs to make the following auditory discriminations: 1) Detection of a noise signal masked by a noise background, the signal differing from the background in one or more of these characteristics: loudness, rhythm, and quality . . . and 2) Recognition of changes in a noise signal masked by a noise background, the usual changes being those of loudness, quality, and rate of rhythmic pulsation."

Thus, the problem of the detection and recognition of passive sonar sounds presents itself as an applied investigation into the psychophysics of auditory discrimination. The majority of research in the area of detection has been concerned with the determination of masked and absolute auditory thresholds as a function of various frequency and intensity relations. Investigations of the function of recognition have been mainly concerned with evolving new training techniques and drill procedures which will enhance retention of the correct labeling responses for the various sounds and will facilitate beneficial transfer of training.

For the study of detection, the parameters varied have been the physical characteristics of amplitude, frequency, complexity, and time. For the study of recognition, the stimuli have been arranged along four major dimensions representing the functional categories to which the sound source may belong.

In nearly all of these investigations the subjective reactions to these sounds, as a possible source of significant variance, have been rather universally ignored. This has been due partly to a lack of objective methodology to handle these qualitative responses; and partly, to a belief among some investigators that these responses are unimportant.

Consequently, much of the psychology of hearing has developed along rather unpsychological lines. As Karlin has put it (5, p. 252):

"All experimentalists agree in taking their start from the physical characteristics of the sound wave. The assumption is made that the physical characteristics of frequency, intensity, complexity, and duration have four functionally distinct corresponding types of auditory function in sense of pitch, sense of loudness, sense of timbre or quality, and sense of time. This assumption does not appear to have been questioned either on theoretical or empirical grounds."

However, with the growth of knowledge in the fields of perception and personality, it has become apparent that how a person will perceive a physical stimulus cannot be fully predicted from a knowledge of the objective characteristics of that stimulus alone. One is forced to consider the "frame of reference" of the perceiving organism. Research has indicated rather clearly that we must take into account what the stimulus <u>means</u> to the organism. (1, 2, 9, 17).

Not many investigators have attempted to vary materials systematically along dimensions of "meaning," however, since adequate control and analysis of such material is not easily accomplished. Only recently have methodological approaches been developed which facilitate this type of experimentation.

The submarine sonarman, faced with the realities of undersea warfare, has had to develop his own "methodology" to analyze the sonar signals and to dimensionalize them in such a way that he may communicate his perceptions to others. In an informal way, a "sonar vocabulary" has developed among sonarmen as an attempt to aid in the detection and recognition of various ship sounds to which the passive-system operator listens. Some sounds are "heavy," others are "light;" some are "bright," others "dull;" some are "hard," others are "soft," etc. The use of such terminology as "heavy," "bright," and "hard" to describe auditory stimuli leads one to suspect that <u>synesthetic</u> or <u>metaphorical</u>

thinking is operative in this judgmental process. Indeed, it is to these qualitative "meaning" dimensions which the sonar operators have intuitively turned for aid in discriminating these complex auditory stimuli.

It appears that "meaning" can no longer be ignored as a source of potential variance in psychophysical studies such as those which deal with the detection and recognition of sonar signals. How "meaning" may be operationally defined and theoretically integrated into a stimulus-response interpretation of behavior will be considered in detail at a later point. First, however, a statement of the hypothesis underlying the research to be presented below will serve to summarize the argument to this point.

B. Basic Hypothesis

It is proposed that the experienced sonarman operates on the basis of an incompletely verbalized semantic frame of reference. Each sonar stimulus is evaluated within this frame of reference and, depending upon the position it occupies in this "meaning space," is judged (or discriminated as) "battleship," "submarine," etc. It seems feasible to structure this frame of reference explicitly, thus providing a standardized "ruler" which may aid in the making of sonar judgments.

It is clear that the sonarman utilizes this "meaning space" when he is required to decode the significance of a sonar signal and to attach to that signal the correct descriptive label. This is the task of recognition. However, it also seems consistent with available evidence (cf. Lawrence's study below) to propose that "meaning" may influence the discriminability of various stimuli.

If this is so, then we may assume that variations in "meaning" and the position of the stimulus in "meaning space" bear an important functional relation to the task of detection as well as to recognition.

C. The Study of Meaning

Semanticists have long realized that "meanings" are complex and multivariate. Recently, Osgood (14) has presented a theoretical analysis of the nature of "meaning" which serves to place this elusive concept within the limits of learning theory and within the possibilities of stimulus-response interpretations. According to his mediational model of language behavior, "meaning" is identified with a mediating response (r_m) which is conditioned to a "sign" ($\boxed{S}$) and which is some fractional component of the original total response (R_t) made to the stimulus (S) for which the sign now stands. This set of relations is shown in the diagram below:

FIGURE 1

Diagrammatic Representation of the Mediational Model of Sign Behavior

$$\begin{tikzcd} S \arrow[rrr] & & & R_t \arrow[dll, dashed] \\ \boxed{S} \arrow[r] & r_m \arrow[r] & s_m \arrow[r] & R_x \end{tikzcd}$$

Osgood states (15, p. 2):

> "I identify meaning with a <u>representational mediation process</u>, a learned state of the organism which, on the decoding side, is elicited by signs and constitutes their <u>significance</u> and, on the encoding side, serves to initiate overt responses [R_x], both linguistic and non-linguistic, and constitutes their <u>intention</u> [s_m]."

One problem of studying "meaning" within this framework is that of describing the dimensions along which these mediating responses may vary.

A highly relevant demonstration of the role that mediating responses may play in behavior is that of D. H. Lawrence (7) in his studies of the acquired distinctiveness of cues. In these experiments he has demonstrated rather clearly how the discriminability of certain stimuli may be enhanced by virtue of being associated with certain mediating responses. These mediating responses, as pure stimulus acts, provide distinctive stimulus inputs which interact with the afferent traces of the external stimulus to modify the molar stimulus trace in such a way as to enhance discriminability. Gagné and Baker (4) have also demonstrated that connecting discriminating verbal responses to stimuli facilitates acquisition of differential motor responses to the same stimuli.

The model which applies to these two studies also may be applied to the learning of significances in which the sonar operator engages. Comparable to the learning of phonemes in the acquisition of language, the sonar operator must learn to make differential responses to those differences among stimuli which <u>make</u> a difference. It is proposed that it is the connotative or mediating responses associated with sonar stimuli which modify these stimuli in such a way as to enhance (or decrease) their discriminability and thus facilitate or retard differential responding.

D. Methodology

1. The Study of Synesthesia

Many early attempts to study the molar stimulus configurations underlying "meaning" centered around the phenomenon of synesthesia. The introspectionist of a decade or two ago was intent upon describing the imaginal responses he found contributing distinctive elements to the conscious content of "meaning."

The literature on synesthesia is replete with cases illustrating the following relationships: tones of different musical instruments may give rise to correspondingly different tridimensional visual shapes (29); color and musical experiences may covary with a high degree of consistency (6); there is a fairly consistent verbal or metaphorical relationship between colors and moods (13); for six different languages studied, there is an association of certain sounds with pleasant meanings and of other sounds with unpleasant meanings (23); there is sometimes remarkable coorespondence between vowels and color even among persons speaking different languages (18); there is a fairly consistent relationship between vowels or consonants and connotative dimensions such as bright-dark, less volume-more volume, etc. (3); and there is a fairly consistent relationship between synesthesia, imagery, and metaphor among the Aztec and Pueblo Indian, Australian Bushman, Siberian Aborigine, Negro (Uganda Protectorate) and Malayan, thus giving some indication of the existence of a pervasive semantic frame of reference (14).

In summarizing the literature on synesthesia, Riggs and Karwoski state (19, p. 39) that every case of synesthesia, whether it is simple or complex, emotional or ideational, consists essentially of a parallel arrangement of two gradients.

"They may be a series of pitches, intensities, wave-lengths, forms, persons, cities, languages, bird-calls, or anything else in keeping with the interests and capacities of the synesthetic."

Osgood, in referring this process of cross-modal translation to the phenomenon of metaphor, has said (14, p. 223):

"The process of metaphor in language as well as in color-music synesthesia can be described as the parallel alighment of two or more dimensions of experience, defined verbally by pairs of polar opposites, with translations occurring between equivalent portions of the continua."

It was thinking similar to this that lead Wheeler and Cutsforth (27), as early as 1922, to attempt to develop a synesthetic theory of meaning. They compared the introspections of two blind subjects (one a synesthete, the other not) in recognizing Braille letters and in developing the meaning of syllables. It was found that the blind synesthete had consistent color associations to certain letters; and that "the color associations of letters <u>mean</u> those letters . . . without those colored associations the process of recognizing could not take place." (p. 368.)

Although the case studied by Wheeler and Cutsforth is complicated by the use of a blind subject as well as the method of introspection, their analysis of the role of synesthetic processes in the development of "meaning" and perception is an extremely useful one. In their theorizing, they place particular emphasis on the motor component of synesthesia as a basic requirement for the development of meaning.

Ignoring for the moment the necessity of specifying the process involved as "synesthetic," it is apparent that what Wheeler and Cutsforth were saying is this: There are some types of mediating processes (in their case, color responses and certain kinaesthetic sensations) which become associated with different experiential datum and which serve as a sort of surrogate phenomena to reinstate the content of meaning and the "feeling of familiarity" which accompanies the perception of "meaningful" stimuli.

2. Objective Methodology

The preceding studies on synesthesia illustrate the lawful relationships which hold between certain stimuli and their connotative associations. Wheeler and Cutsforth have rightly recognized the role played by mediational processes (such as synesthetic "imagery") in the development of meaning. It has already been hypothesized that it is the stimulus components of these mediational responses, interacting with the afferent stimulus input, which gives our perceptions their distinctive character (i.e., their meaning) and which aid in differentiating similar stimulus inputs one from the other.

The early studies of meaning and synesthesia were all hampered, however, by the lack of objective methodology. With further development of psychophysical techniques, and especially psychological scaling methods, new avenues have been opened for the study of meaning.

Most psychologists hold that behavior is correlated with scale values of the stimulus situation as that situation might be quantified along certain objective dimensions. The science of psychology is, in much of its endeavors, still in the process of defining these stimulus dimensions. For many years, the behaviorist was content merely to observe the overt responses of his experimental organisms and to formulate functional relationships between observable molar responses and the observable molar stimulus situation. But the vigorous demands for more precise prediction, especially in the field of applied research, has necessitated greater differentiation of the stimulus-response complex and has led to more detailed analysis of the complex components of these observable phenomena.

Attacking the problem systematically, one of the greatest aids in this "refining" procedure has been the development of the statistical techniques for multidimensional scaling. By means of these techniques, it is possible to determine to what psychological dimensions the organism is responding when it is placed in a complex stimulus situation.

Torgerson (25) has presented what may be considered the most general development of this procedure. His technique requires no _a priori_ assumptions as to what dimensions might be operative in a given judgmental situation, but rather extracts these dimensions after the subjects have structured the situation in terms of the "similarity" of the stimuli one to the other. Realizing that similarity is not a quality in and of itself, but rather may be considered only with respect to specific dimensions, Torgerson employs a modification of Young and Householder's technique (28) to translate these similarity relationships into absolute distances. He then projects these distances into Euclidian space and structures this space with as many statistical dimensions as are necessary to account for the common variance. Interpretation of these dimensions in terms of their psychological meaning is the final step in this process.

It is also possible, however, to scale a complex stimulus situation along multidimensional lines by first assuming that certain dimensions are operative in that particular situation and, by including many such dimensions, more or less "blanket" the possibilities. Then, through factor analysis, one may reduce the number of dimensions to a minimal quantity having maximal differentiating power.

The technique of listing many dimensions at the very outset and then organizing them into independent clusters by the method of factor analysis has been employed by Osgood and Suci (16) in the multidimensional analysis of meaning and is the procedure to be utilized in this paper.

Before turning to this, however, some other attempts to study the "meaning" of stimuli may be briefly examined. Since this paper is concerned with the meaning of complex auditory stimuli, comment will be confined to studies which deal primarily with this type of variable. Different experimenters have used vowel and consonant sounds, words and word combinations, complex tones, pure tones, ship sounds, and marine sounds of biological origin.

Fischer-Jorgenson (3) has made an attempt to verify experimentally the notion that the "meaning" of certain sounds might contribute to the distinctiveness of those sounds. Her interests were primarily in demonstrating that certain vowel and consonant sounds are consistently associated with certain connotative meanings (mediating responses). If such a relation were proven to hold with fair reliability (as her preliminary findings -- reported above -- seem to indicate will be the case), then such onomatopoetic relationships could be used as a descriptive basis for phonemic analysis.

Mosier (11) was one of the first to attempt a systematic, psychometric study of meaning. He had subjects rate 296 words and word combinations on an eleven-point scale of favorableness-unfavorableness. The distribution for most words turned out to be Gaussian about some well defined central tendency, thus lending support to the belief that it is possible to study meaning in a quantitative way. Mosier's technique, however, lacked the multi-dimensionality required to do justice to the polyvariate nature of meaning. Although he used the technique of assuming _a priori_ dimensions to structure the semantic space of "meaning," he utilized only _one_ dimension in his study, i.e., favorable-unfavorable.

Lichte (8) attempted to demonstrate that certain psychological "meanings" are dependent upon (or at least concomitantly vary with) certain changes in the nature of the physical stimulus. He found that systematic variation of the intensity relations among the 16 partials of a fundamental tone of 180 cps causes the tone to vary concomitantly on certain psychological scales such as "bright-dull" and "full-thin." For example, a "full" tone is one in which the _odd_ numbered partials are relatively attenuated, whereas a "thin" tone is one in which the _even_ numbered partials are relatively attenuated. As another example, a "bright" sound is defined by tones with the lower partials relatively attenuated, while a "dull" tone is one in which the 12th through 15th partials are relatively attenuated. When a series of tones intermediate between these two extremes is rated by the paired comparisons method (as to "first tone brighter or duller than the second?") a linear relation is found to hold between the psychological scale value and the partial intensity relations within the complex tone. Again, however, this experimenter utilized only a limited number of possible psychological dimensions.

The complex nature of the problem was recognized by Salmon, but he did not attempt to be exhaustive in his methodology. He stated (20, p. 731):

> "As with musical instruments, the final acceptance of a sound system is largely determined by its performance in a carefully conducted listening test before a sound jury. The judgments of the jury are usually expressed in terms suggestive of the subjective reactions [mediating responses] produced by specific characteristics of the reproduced sound. Many of these terms are related to tactile sensations, while many may only be described by reference to the program material."

Salmon attempted to discuss some of the descriptive terms in the light of the related objective characteristics of the stimulus and to give tentative definitions as a preliminary to possible standardization.

In the area of Naval research, a Management and Marketing Research Corporation report (31) presents a preliminary attempt to study the useful mediating cues isolated by sonar operators by having sonarmen rank descriptive adjectives in their order of helpfulness in aiding ship sound recognition. The report states (p. 22):

> "The major conclusion to be drawn here is that there appear to be differential patterns of helpful cues which are used in the identification of M [motorboat], P [passenger], and T [tramp] ships. No such obvious patterns are evident in the case of the confusing cues."

Finally, a study by Small (21) attempted to derive a limited set of descriptive terminology to characterize the various sounds of biological origin which are heard over sonar gear aboard naval vessels and commercial boats. He had the audience at the 1947 meeting of the Acoustical Society of America indicate which adjectives on a given list are most closely associated with which one of a given number of sounds. He found that it was possible to derive a list of nine categories, if one were willing to sacrifice the greater accuracy which was gained by using a longer list.

3. <u>The Semantic Differential</u>

Consistent with the preceding studies on the measurement of meaning and the studies of synesthesia, Osgood has proposed the following hypotheses (14, p. 227):

> "1) The process of description or judgment can be conceived as the allocation of a concept to an experiential continuum, definable by a pair of polar terms.
>
> "2) Many different experiential continua, or ways in which meanings vary, are essentially equivalent and hence may be represented by a single dimension.
>
> "3) A limited number of such continua can be used to define a semantic space within which the meanings of any concept can be specified."

Accordingly, he has undertaken a series of factor analyses in an attempt to determine these continua.

Although Osgood is essentially interested in deriving the basic connotative dimensions underlying the judgment or significance of verbal stimuli, it is reasonable to propose that his technique may be used as a generalized procedure for the scaling of <u>any</u> set of variables thought to vary along common dimensions. Thus, in the light of the previously cited findings in the area of synesthetic thinking, Osgood's hypotheses might be paraphrased to read as follows: the process of description or judgment can be conceived as the allocation of <u>any presented stimulus</u> to experiential continua, definable by pairs of polar terms; many different experiental continua are essentially equivalent and hence may be represented by a single dimension; and a limited number of such continua can be used to define a semantic space within which the meaning of any presented stimulus can be specified.

It would seem, therefore, that Osgood's methodology is a useful and objective technique for the development of a classificatory scheme by which auditory stimuli might be scaled in terms of meaning. Once such meaning dimensions were derived, variation along these dimensions could be identified as one aspect of the operations underlying the process of auditory discrimination. For again, remembering Lawrence's studies, it may be assumed that the discriminability of stimuli rests, to some extent, upon the distinctive mediating responses associated with them (i.e., their meaning).

The graphic form of the Semantic Differential consists of a paper-and-pencil test wherein the subject is required to allocate a concept (or any presented stimulus) within a given system of descriptive dimensions by means of a series of independent associative judgments. The subject is presented with a pair of descriptive polar terms and a stimulus to be judged. The task consists in indicating, with a pencil check mark, which of the polar terms applies to the stimulus. In the graphic form, which will be employed in this study, the subject indicates the intensity of his association by the extremeness of his checking on a seven-point scale. The polar terms are presented at the opposite ends of the seven-step continuum, thus indicating that a judgment of 1 or 7 is the most extreme, with a judgment of 4 indicating either "neutrality" or equal association to both ends of the scale.

By assigning numbers 1 through 7 to the intervals on the scale it is possible to quantify the "meaning" of any one item, as well as to express the relationship between items and scales (14, 15). It is useful to consider such a procedure as an operational definition of "meaning" (within our given system), and any two stimuli having exactly the same checking on all scales in the differential may be said to have the same connotative meaning.

The application of Osgood's multidimensional scaling technique to the auditory discrimination problems involved in the isolation and identification of sonar recognition cues may be logically divided into three sequential phases: 1) the compilation of a series of descriptive scales upon which sonar sounds may be assigned quantitative values; 2) the determination of the meaningfulness of this task by an analysis of the consistency with which an experimental population assigns certain sonar sounds to certain positions on these scales; and 3) a factor analysis of the intercorrelations between scales to derive a limited number of general dimensions of meaning having maximal differentiating power. These three phases shall be treated below as Experiments #1, #2, and #3, respectively.

II. PROCEDURES AND RESULTS

A. Experiment #1: Compilation of Descriptive Scales

A sample of 50 seven-point scales was selected, each scale being defined by a pair of polar-opposite adjectives. The scales were obtained from the following sources:

1) A preliminary study was run on 26 college students at the University of Illinois. The subjects were asked to write as many descriptive words as they felt applied to various passive sonar recordings. A series of twenty-six sample recordings dubbed from the training records used by the Navy for instruction of sonar operators was presented to a population of 26 undergraduate journalism students. These students had received specialized training in advertising techniques designed to increase their facility for adequate verbal description. Each sample recording was presented for a period of seven seconds. The list of twenty-six items was divided into two lists of 13 each, and then seven of the items from each list were repeated in a random fashion, making each list contain a total of 20 items. The subjects were divided into two groups. Group I, consisting of 14 S's, was presented list 1. Group II, consisting of 12 S's, was presented list 2. Both groups were given the following instructions at the beginning of the test period:

> You are going to hear some sounds which I want you to attempt to describe. After hearing each sound, you are to write down as many descriptive words as you feel are appropriate to describe the sound. Any descriptive word you feel would characterize the sound will do. Also, you may use short descriptive phrases if you wish. It is important to know that these sounds are different from one another (although many may sound alike). Try to describe each one uniquely. Remember, we are looking for a list of as many words as we can find that will fully describe each individual

> sound. Let yourselves go and use your imagination. You may use qualities from <u>any</u> of the senses to describe the sounds; that is, some may suggest colors, others intensities, smells, touch sensations, or what have you. Others may suggest common experiences such as household sounds, musical melodies, rhythms, mechanical noises, etc. And yet, others may suggest simple descriptive adjectives. Be sure to write down each of these things if the sounds call them to your mind.

The resulting descriptive terms were tabulated in a frequency distribution and from a representative sample of the most frequently occurring words a list of adjective pairs was secured with which to form bi-polar scales.

Other sources of descriptive terminology were:

2) A list of scales being used at the University of Illinois in a study of aesthetic judgments.

3) Rational analysis of the sensory inputs of the human organism.

4) The list of high ranking helpful sonar recognition cues presented in the report entitled "An Experiment in Ship Classification Teaching Methods" (31).

5) The list of scales used in a factor analytic study of the dimensions structuring the semantic space of "meaning" (16).

Table 2 presents the final list of 50 adjective pairs utilized in the present study.

B. <u>Experiment #2: Consistency of the Connotative Associations to Passive Sonar Sounds</u>

Since the major objective of Experiment #2 was to determine the consistency with which scale values are assigned to various stimuli, only four sonar sounds were used. Each sound was judged on each of the 50 scales. Thus, each subject was required to make a total of 200 associative judgments. The stimuli chosen for this study had the following major characteristics:

Sound 1: Typical multiple-screw character, irregular beats and indefinite pattern. (Type A).

Sound 2: "Putt-putt" quality, light beats. (Type B).

Sound 3: Heavy accent, each beat laboring. (Type C).

Sound 4: Shaft whine, accented beat, minor beats not heard. (Type D).

As indicated by the designations in parenthesis following each description above, an attempt was made to make these sounds representative of each of the four functional categories of ship sounds currently used by the Navy. For security purposes, these categories shall be designated A, B, C, and D; these categories are represented by sound 1, 2, 3, and 4, respectively.

Figure 2 presents the sound spectrograms of these four stimuli. These recordings were analyzed on a Kay Sona-graph. This instrument portrays the frequency region up to 8000 cps in a vertical distance of 4 inches and covers a period of time equivalent to 2.4 seconds for a horizontal distance of approximatly 12½ inches. Frequency in kilocycles is indicated on the ordinate; time in seconds is indicated on the abscissa; and intensity is indexed by the density of the trace.

The stimuli were presented in a rotated, randomized fashion. Each stimulus was presented for 5 seconds, followed by a 4-second silence. After every fifth item, a 3000 cps tone sounded to aid the subjects in keeping their place while taking the test. Figures 3 and 4 present copies of the instruction sheet and the answer sheet respectively and indicate the manner in which the scales were presented to the subjects.

FIGURE 2

SOUND SPECTROGRAMS OF FOUR REPRESENTATIVE STIMULI

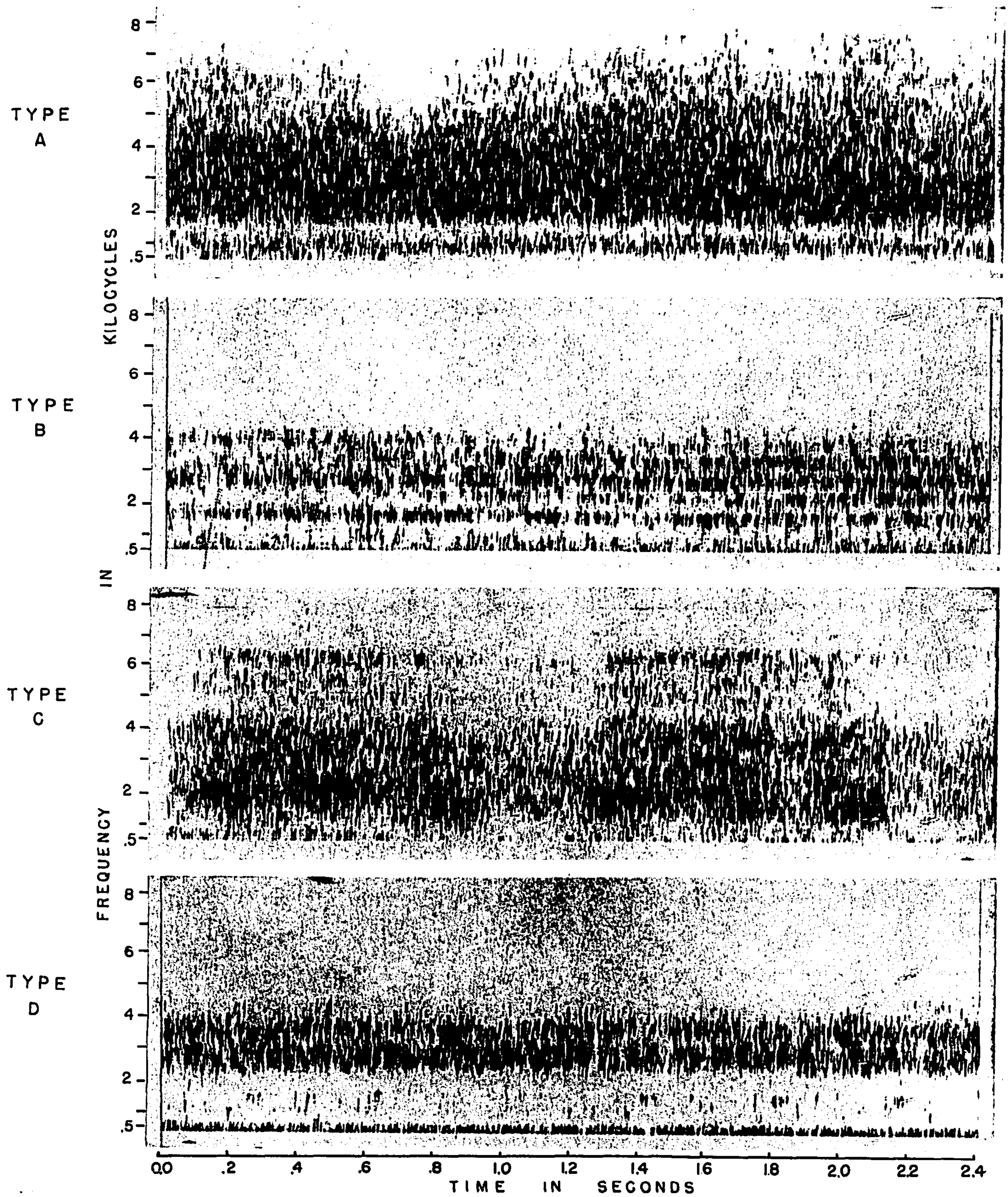


FIGURE 3 - INSTRUCTION SHEET

The purpose of this study is to measure the meanings of certain sonar sounds to various people by having them judge each sound against a series of descriptive scales. In taking the test, please judge the sounds on the basis of what they mean to you. Each item on the test presents a sound and a scale paired together. You are to rate the sound on the seven-point scale indicated. You will hear the sounds for five seconds, followed by a four second silence.

You will notice on the answer sheets that the scales are grouped into bunches of five. This is to aid you in keeping your place while taking the test. After every fifth item, you will hear a musical tone. This "beep" is to indicate to you that you should be starting the next group of five scales when the next sound is presented.

If you feel that the sound is very closely associated with one end of the scale, you might place your check-mark as follows:

crisp _✓_:____:____:____:____:____:____ soggy

If you feel that the sound is quite closely related to one side of the scale, you might check as follows:

stormy ____:_✓_:____:____:____:____:____ calm

If the sound seems only slightly related to one side as opposed to the other, you might check as follows:

thick ____:____:_✓_:____:____:____:____ thin

If you consider the scale completely irrelevant, or that both sides are equally associated, you would check the middle space on the scale:

idealistic ____:____:____:_✓_:____:____:____ realistic

IMPORTANT: (1) Place your check-mark in the middle of the spaces, not on the boundaries:

THIS NOT THIS

____:____:_✓_:____:____:____✓____

(2) Never put more than one check-mark on each scale.
(3) Be sure you check each item -- do not omit any.
(4) Make your response as soon as you can after the sound begins.

Sometimes you may feel as though you have had the same item before on the test. However, please do not look back and forth through the test. Also, do not try to remember how you marked similar items earlier in the test. Make each item a separate and independent judgement. You will work at fairly high speed, so do not worry or puzzle over individual items for long periods. It is your first impressions that we want.

Since this test is going to be given in two sessions, please print your name below for identification purposes:

NPS, SAN DIEGO

NAME: ________________________________

FIGURE 4

ANSWER SHEET

(Sample Portion)

heavy	___:___:___:___:___:___:___	light
dry	___:___:___:___:___:___:___	wet
safe	___:___:___:___:___:___:___	dangerous
concentrated	___:___:___:___:___:___:___	diffuse
pushing	___:___:___:___:___:___:___	pulling
labored	___:___:___:___:___:___:___	easy
bright	___:___:___:___:___:___:___	dark
even	___:___:___:___:___:___:___	uneven
tight	___:___:___:___:___:___:___	loose
relaxed	___:___:___:___:___:___:___	tense
colorful	___:___:___:___:___:___:___	colorless
hot	___:___:___:___:___:___:___	cold
rich	___:___:___:___:___:___:___	thin
obvious	___:___:___:___:___:___:___	subtle
wide	___:___:___:___:___:___:___	narrow

The sounds were recorded on magnetic tape and played over a Magenecorder through a 12-inch speaker mounted in a baffle box. The sound level in the test room was between 86 and 90 db when the stimuli were "on," and 52 db when the stimuli were "off."

The subjects, 16 men, each took the test twice, separated by a period of five days. The seating arrangement and speaker placement were the same for both test sessions.

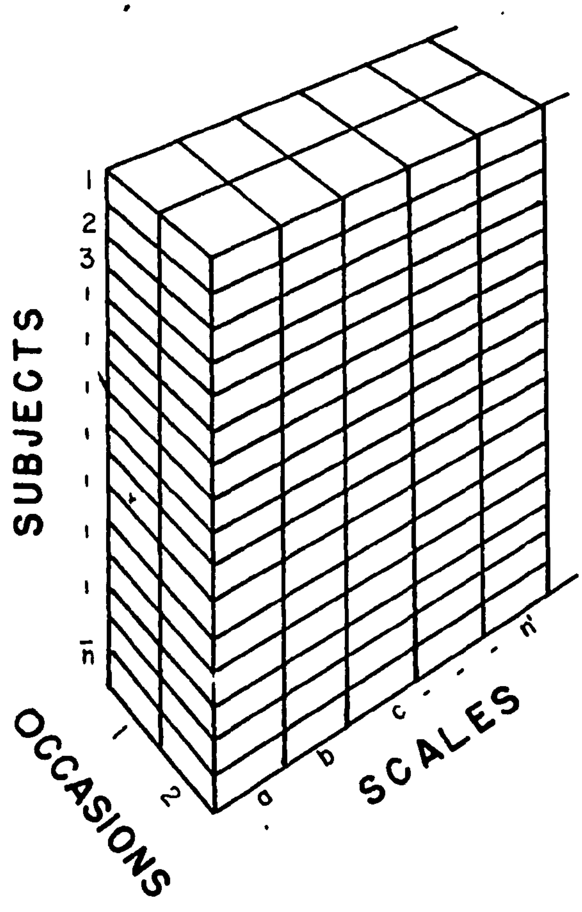
The data from this consistency study could be entered into a three-dimensional table. Such a table is presented as Figure 5 to aid the reader in visualizing the manner in which the data of this study may be organized.

From this table it is possible to calculate the consistency of the judgments called for by the experimental procedure.

However, in order to test the consistency of the judgments made by the subjects in this study, it was necessary to develop a statistical test which would not be influenced by the magnitude of the variance of the responses to any given stimulus-scale pair, — that is, variance within any column of cells in Figure 5. At first it would seem a rather straightforward procedure merely to run a Pearson product-moment correlation between the scale values assigned by all 16 subjects the first time and the second time, for any given stimulus-scale pair. However, considering the case in which all subjects might assign the <u>same</u> scale position to the stimulus, the variance for that measure would be zero. In a theoretical case, if everyone picked position 1 the first time and position 1 the second time, the reliability would be perfect, but the computed correlation would be indeterminate (due to complete

FIGURE 5

ORGANIZATION OF DATA FOR CONSISTENCY STUDY



lack of variance), and would be a meaningless solution. Obviously, some other measure of consistency is required to serve as an index here.

Let us assume that the subjects assigned their scale values in a purely random fashion. Let D_i be the absolute value of the difference between ratings made by the i-th subject for a given stimulus-scale pair; and let S_n be the sum of the D_i for n subjects. The subscript of the variable S will always indicate the total number of subjects considered. Assuming that each subject rates entirely by chance, then for a single subject, all the equally likely $D_i = S_1$ are shown in Table 1.

Table 1

Values of S_1

		Value assigned the second time						
		1	2	3	4	5	6	7
	1	0	1	2	3	4	5	6
Value	2	1	0	1	2	3	4	5
assigned	3	2	1	0	1	2	3	4
the first	4	3	2	1	0	1	2	3
time	5	4	3	2	1	0	1	2
	6	5	4	3	2	1	0	1
	7	6	5	4	3	2	1	0

The body of Table 1 contains all of the possible absolute difference values one subject could obtain. From this table it is possible to arrive at the theoretical frequency with which one would expect to find a difference of a given magnitude if one subject were assigning scale values at random in a test-retest situation.

This reasoning may be generalized to 16 subjects and a summated difference value (S_{16}) substituted for the difference values of one subject (S_1). Also, since there are four S_{16} values for each scale, we may average these values to arrive at the average $\bar{S}_{16}$ for each scale. (See the Appendix of (22) for the complete derivation of this distribution of difference values for 16 subjects.) From this distribution it is possible to determine the $\bar{S}_{16}$ value which would be significant at the 1 per cent and 5 per cent levels of confidence. These critical values are 28 and 31 respectively. These values may be interpreted as follows: an $\bar{S}_{16}$ value as small or smaller than 28 could have occurred only one time in 100 if pure chance were the only factor determining the consistency of the subjects' judgments. Thus, an $\bar{S}_{16}$ value of 28 or less would seem to indicate that there was some factor other than chance determining the judgments of the subjects from one time to the next.

Table 2 presents the obtained S_{16} values for each stimulus-scale pair. The average $\bar{S}_{16}$ for each scale has been calculated and entered in the last column. It can be seen from this column of average $\bar{S}_{16}$'s that all scales have an average consistency at or beyond the 1 per cent level of confidence. That is to say, we are testing the null hypothesis that subjects make their ratings by chance against the alternative hypothesis that subjects are consistent in their ratings. The data indicate that we may reject the null hypothesis at or beyond the 1 per cent level of confidence for all 50 scales.

There are three criticisms which may be advanced against the statistic employed in Experiment #2. First, it may be contended that although a significant deviation from the chance level of responding has been demonstrated, this does not indicate that this task is a meaningful one to the subject required to perform it.

TABLE 2

Summated Absolute Difference Values for Sixteen Subjects

Scale	Stimulus 1	2	3	4	Average
1. pleasant-unpleasant	18	24	12	7	15
2. repeated-varied	22	16	20	18	19
3. smooth-rough	15	28	28	19	23
4. active-passive	14	18	21	27	20
5. beautiful-ugly	21	22	22	13	20
6. definite-uncertain	19	23	26	14	21
7. low-high	13	10	11	16	13
8. powerful-weak	31	18	16	9	19
9. steady-fluttering	25	22	28	14	22
10. soft-loud	17	22	24	17	20
11. full-empty	20	18	16	12	17
12. good-bad	11	16	25	29	20
13. rumbling-whining	12	14	14	6	12
14. solid-hollow	18	26	24	10	20
15. clear-hazy	15	26	21	18	20
16. calming-exciting	11	21	23	15	18
17. pleasing-annoying	14	22	15	19	18
18. large-small	17	17	17	16	17
19. clean-dirty	9	17	13	20	15
20. resting-busy	16	17	25	16	19
21. dull-sharp	12	20	16	13	15
22. deep-shallow	12	21	15	17	16
23. gliding-scraping	30	16	15	18	20
24. familiar-strange	27	32	22	20	25
25. soft-hard	18	17	19	15	17
26. heavy-light	20	10	10	8	12
27. wet-dry	25	17	18	18	20
28. safe-dangerous	11	23	29	14	19
29. concentrated-diffuse	17	17	16	27	19
30. pushing-pulling	20	26	20	29	24
31. labored-easy	24	11	21	22	20
32. dark-bright	14	15	20	16	16
33. even-uneven	29	15	17	18	20
34. loose-tight	28	19	21	19	22
35. relaxed-tense	9	15	25	21	18
36. colorful-colorless	18	21	19	24	21
37. hot-cold	20	9	24	12	16
38. rich-thin	15	20	18	19	18
39. obvious-subtle	11	18	9	26	16
40. wide-narrow	24	13	18	21	19
41. deliberate-careless	15	18	20	12	16
42. happy-sad	13	18	16	15	16
43. gentle-violent	10	20	19	12	15
44. mild-intense	14	27	17	23	20
45. rounded-angular	15	18	16	18	17
46. slow-fast	13	15	29	15	18
47. rugged-delicate	20	21	15	17	18
48. simple-complex	16	18	15	34	21
49. green-red	21	15	14	18	17
50. masculine-feminine	16	18	20	16	18

Indeed, it would be possible to obtain complete consistency in ratings if all subjects rated all sounds by checking the "4" position on all scales. This would indicate that, in fact, the task was consistently meaningless to the subjects. Unless it can be demonstrated that the responses did not pile up at the "4" position on the scales, it can not be assumed that the judgments to be analyzed in Experiment #3 represent meaningful psychological data.

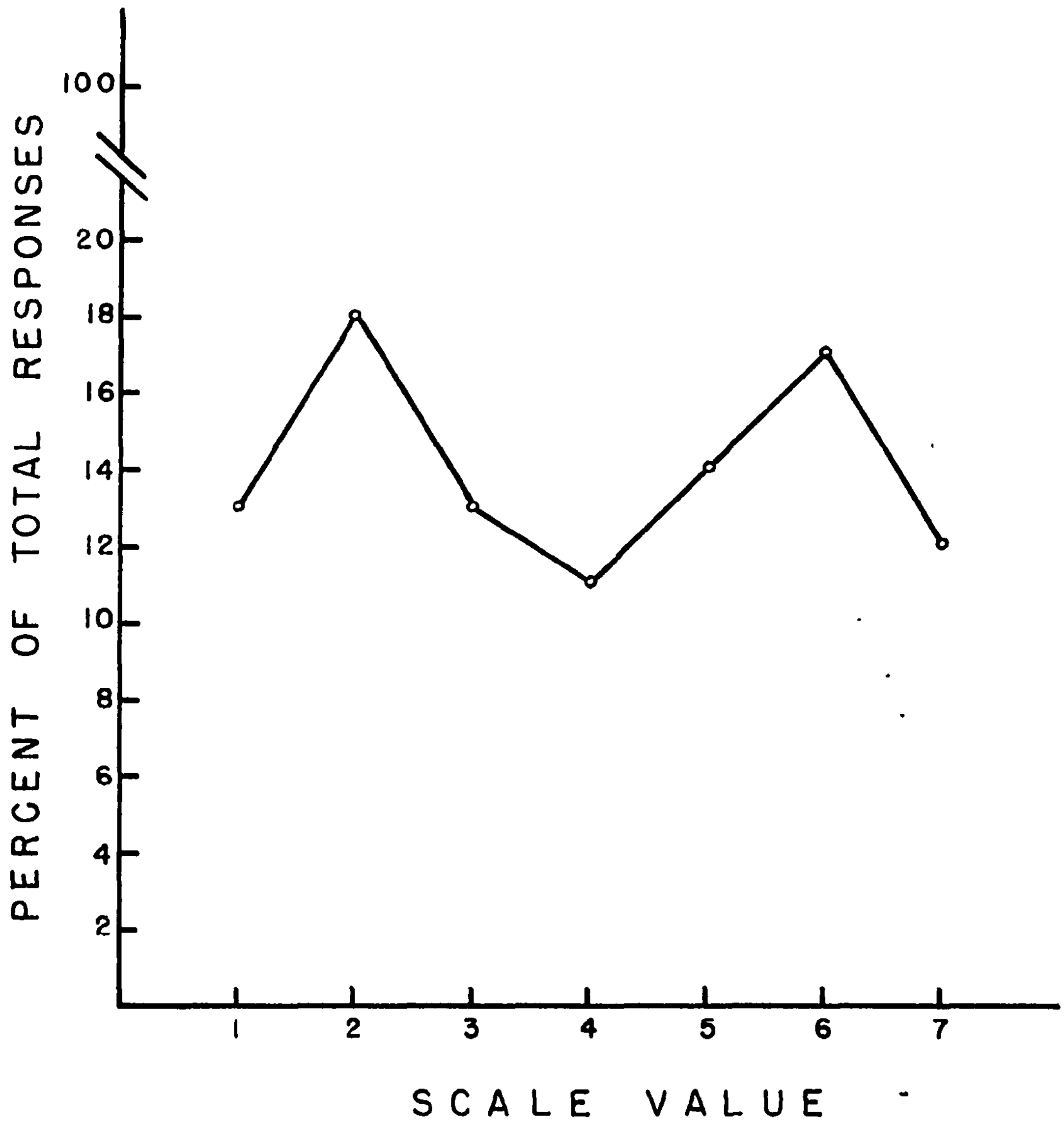
Secondly, the statistical test of consistency in rating utilized involves the assumption that all scale values on the seven-point scale have approximately an equal probability of being used. If a frequency distribution of responses (plotted against scale value) turned out to be markedly skewed, then this assumption would not be met.

Figure 6 is presented in answer to these two criticisms. It may be seen from this figure that the responses do not pile up at the "4" position, but, rather, that position "4" has relatively the least number of responses. It is also apparent from Figure 6 that there is no marked skewing evident in the plot, although the magnitude of the ordinate scale tends to exaggerate apparent differences. Indeed, application of the Kolmogorov-Smirnov test of goodness of fit (26), using the minimum estimate for number of independent judgments (i.e., 16), indicates that one may not reject the hypothesis that the best fitting curve for these data is a straight line (alpha equal to or less than .05 is between 5 and 6; obtained ND_{alpha} equals .704).

FIGURE 6

Distribution of Responses Obtained in Consistency Study

(N = 3200)



The third criticism is again directed against the assumption of equiprobability of usage for all scale positions. It may be contended that one need not utilize this assumption, but, rather, may calculate, from the empirical data, the expected frequency with which each scale position should be used under the assumption that the first and second testing sessions are completely independent. Once this expected frequency is known, it is then possible to calculate the theoretical frequency with which one would expect to obtain differences of a given magnitude between a first and a second testing.

With this in mind, the scale was picked from Table 2 which showed the <u>least</u> consistency. This turned out to be scale #24. The 64 responses (four from each of sixteen subjects) were plotted, in scattergram fashion, in a 7 x 7 matrix. Rows represented the value checked in the first test session, columns represented the value checked in the second test session. Marginal totals were then used to calculate the expected frequency for each cell in the matrix under the hypothesis that the two testing sessions were independent. The expected frequencies were then summed for the principal diagonal to yield the expected frequency of obtaining a difference score of zero. Similarly, the expected values in the diagonals representing absolute differences of one, two, three, four, five and six were summed to obtain their respective theoretical frequencies.

A chi-square test of independence was then run between the expected and obtained frequencies for difference values of zero, one, two, three, four, five and six. The chi-square value obtained was 8.808, which, with 6 degrees of freedom, is not statistically significant, although it closely approaches the 5% level of confidence (with a one-tailed test, P is contained in the interval .10 - .05). This may be interpreted as follows: the difference between the expected and obtained difference scores on the least consistent scale was not quite large enough to cause rejection of the null hypothesis that the first and second test sessions were independent. However, it follows that the rest of the scales, showing greater consistency than scale #24, would yield values of chi-square of even greater statistical significance than that obtained above. This means that, considering the rest of the scales in order of increasing consistency, these scales would yield values of chi-square which allow rejection of the null hypothesis at increasing levels of confidence. The consistency of the behavior sampled (i.e., the non-independence of the first and second testing sessions) thus appears to be substantiated.

C. Experiment #3: A Factor Analysis of the Connotative Associations to Passive Sonar Sounds

The major portion of this investigation consists of a factor analysis of the inter-correlations between the 50 scales derived in Experiment #1.

1. Subjects: The subjects employed in Experiment #3 were 50 naval sonarmen, on active duty in the Navy, with median sonar experience of one year.

2. Apparatus: The stimuli used in Experiment #3 were 20 selected recordings of passive sonar sounds taken from the records utilized by the Navy to train sonar operators. Each sound was recorded on a loop of magnetic tape in such a way that when the

tape loop was played on a Magnecorder it produced an auditory stimulus of a continuous nature. Care was taken to avoid adding any fortuitous characteristics to the sounds by virtue of the nature of the recording technique.

The twenty sounds consisted of five representatives from each of the four major categories of sounds as they are differentiated by the Navy. Four additional Type A, Type B, Type C, and Type C sounds were added respectively to each of the four sounds utilized in Experiment #2. Thus, the sounds depicted in Figure 2 constituted stimuli 1, 2, 3, and 4 in Experiment #3. The additional sounds utilized are presented in Figures 7 (Type A), 8 (Type B), 9 (Type C) and 10 (Type D) with their stimulus number indicated in the left hand margin.

The sounds were presented to the subjects over a Western Electric #755 speaker mounted in the center of the ceiling of a sound proof room. The subjects sat around the perimeter of the room so that all subjects were approximatly equidistant from the sound source.

The sound proof room was mounted on a converted Navy landing craft (LCM) and this craft was moored, during the test sessions, in San Diego bay alongside the submarine from which the subjects were obtained.

3. Experimental Procedure: The sounds were presented one at a time to the subjects (at -5 db; re: 1 MW, 600 ohms) and allowed to play continually until the last subject had rated a given sound on the last scale. Then the next sound was presented and, in the same manner, continued until all subjects had rated it on all 50 scales. This procedure took advantage of whatever

FIGURE 7

SOUND SPECTROGRAMS OF TYPE "A" STIMULI

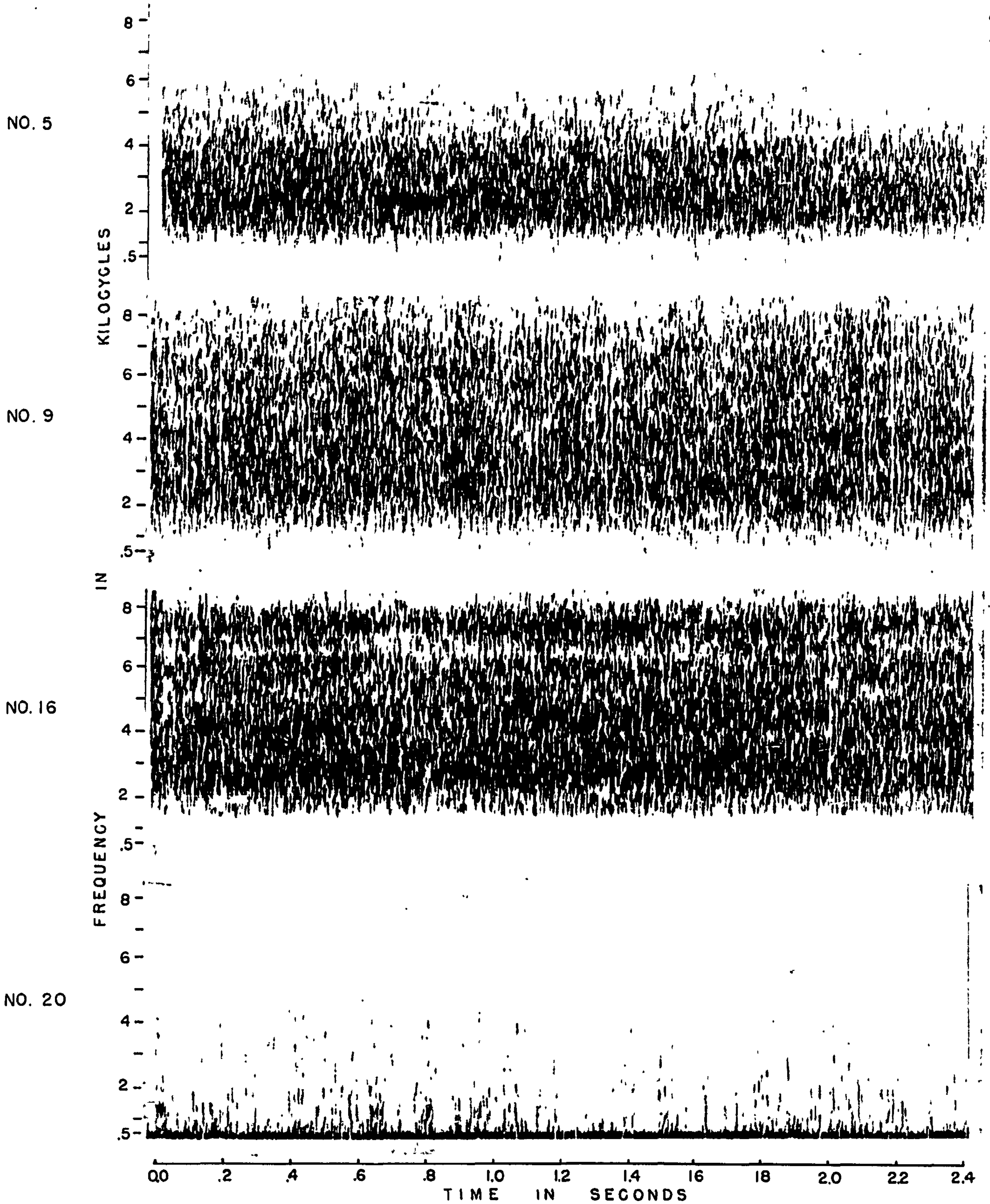


FIGURE 8

SOUND SPECTROGRAMS OF TYPE B' STIMULI

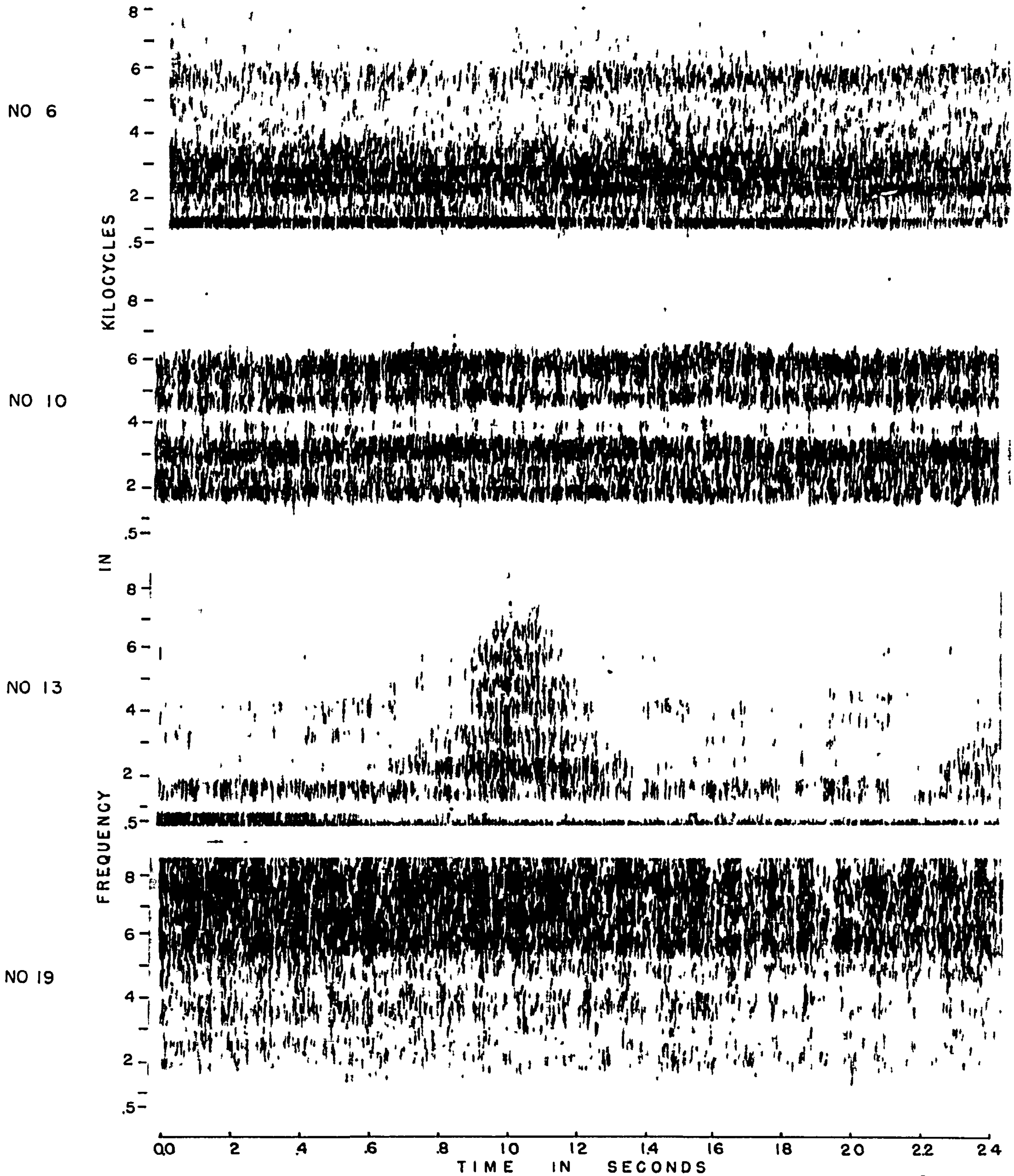


FIGURE 9

SOUND SPECTROGRAMS OF TYPE "C" STIMULI

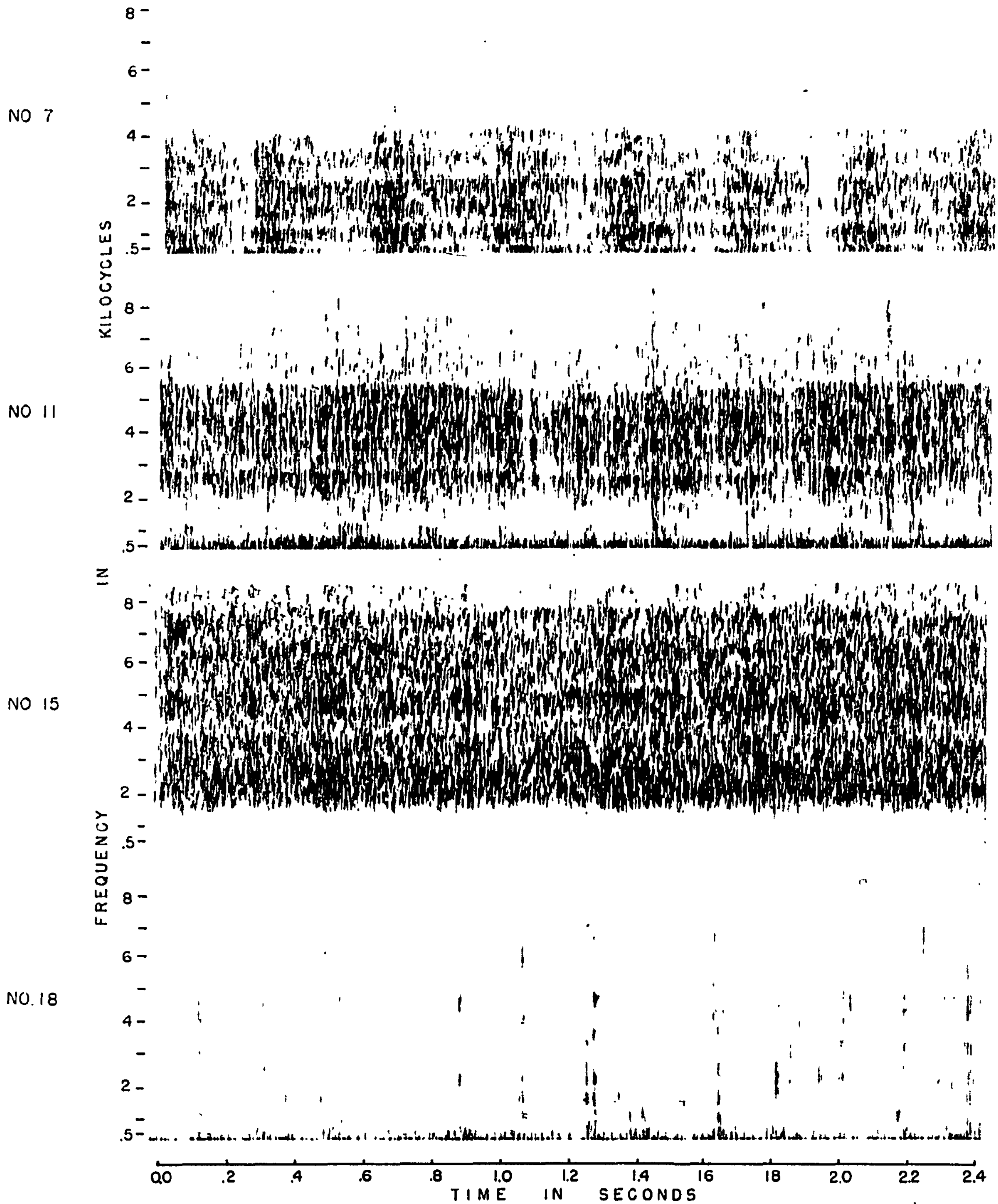
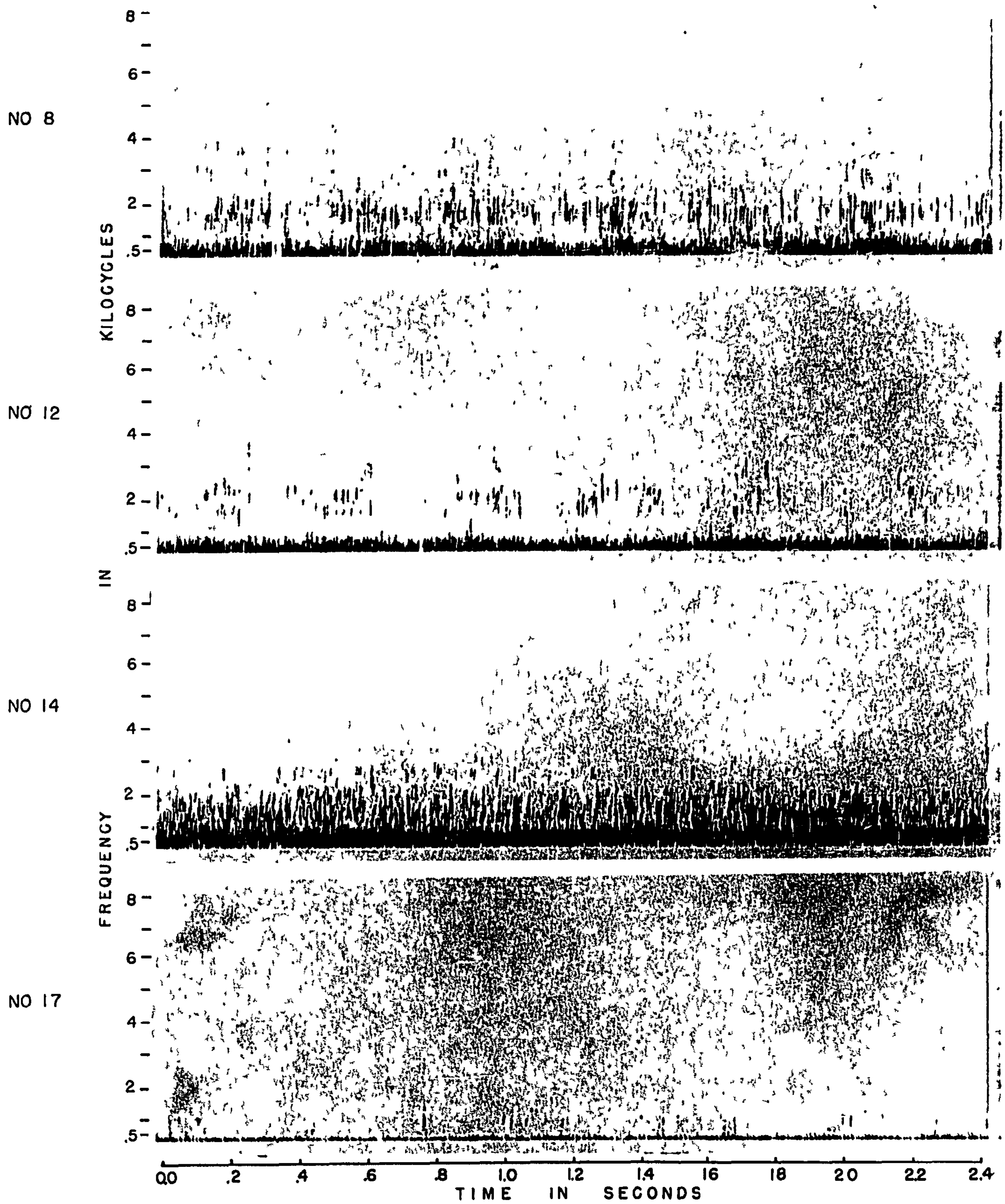


FIGURE 10

SOUND SPECTROGRAMS OF TYPE "D" STIMULI



"halo" effect it might produce, rather than attempting to control, it in order to insure that the total connotative-denotative significance of the sound was involved in the rating scale judgments.[1]

The instruction sheets and answer sheets were the same as those employed in Experiment #2 (see Figures 3 and 4), with the exception of the following minor changes: On the instruction sheet, the last sentence of the first paragraph and the entire second paragraph were deleted. On the answer sheets, the sound number to be evaluated was indicated at the beginning of each group of 50 scales. At the end of the 50 scales, the word "stop" appeared to prevent subjects from going on to the next group of scales until the next sound was presented.

The combination of scales, sounds and subjects may be organized into a 50 x 20 x 50 cube of data such as that diagrammatically presented in Figure 11. Each cell contains a number from 1 to 7 representing the judgment of a particular sound on a particular scale by a particular subject. The raw data were punched into IBM cards in such a way that each subject had a separate card for each sound, with the scales running in consecutive order from 1 to 50. The total deck of IBM cards thus contained 50 (subjects) times 20 (sounds), or 1000 cards, each holding 50 scale position numbers in consecutive order. In order to obtain a correlation matrix which would be most representative of the general sonar culture (that is, subjects and sounds in general), the summations for

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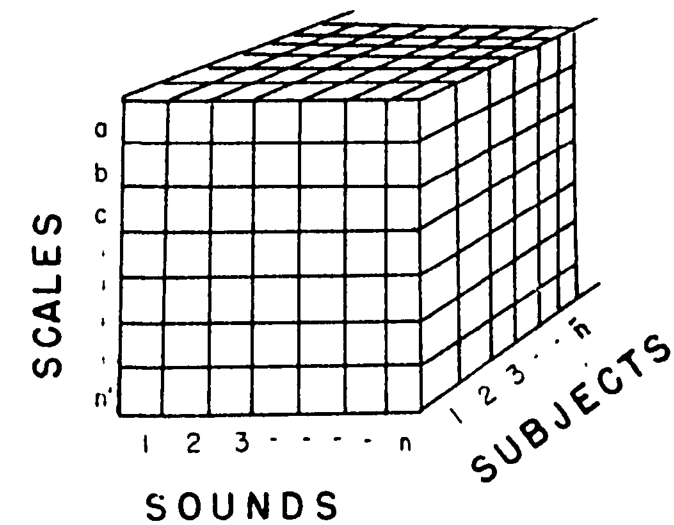
1. Unpublished data collected by Jean Kerrick at the University of Illinois demonstrates that there is actually no difference between results obtained by this procedure and results obtained by the procedure employed in Experiment #2 above.

FIGURE 11

ORGANIZATION OF DATA FOR FACTOR ANALYSIS STUDY



$$r_{ab} = \frac{N \sum_{i=1}^{n} \sum_{j=1}^{\bar{n}} (ab)_{ij} - \sum_{i=1}^{n} \sum_{j=1}^{\bar{n}} a_{ij} \cdot \sum_{i=1}^{n} \sum_{j=1}^{\bar{n}} b_{ij}}{\sqrt{\left[N \sum_{i=1}^{n} \sum_{j=1}^{\bar{n}} a_{ij}^{2} - \left(\sum_{i=1}^{n} \sum_{j=1}^{\bar{n}} a_{ij}\right)^{2}\right] \left[N \sum_{i=1}^{n} \sum_{j=1}^{\bar{n}} b_{ij}^{2} - \left(\sum_{i=1}^{n} \sum_{j=1}^{\bar{n}} b_{ij}\right)^{2}\right]}}$$

cross-products, means, and variances of every scale with every other scale were taken across both subjects and sounds, as indicated by the modified Pearson product-moment correlation formula which appears in Figure 11. This had the additional advantage of avoiding spuriously low correlations resulting from reduced variability of judgments on single sound-scale pairings such as was discussed in Experiment #2.

The 50 x 50 correlational matrix generated in this fashion (giving the correlation of each scale with every other scale) was factor analyzed using Thurstone's complete centroid method (24). The correlation matrix is presented in the Appendix. Eight factors were extracted from the data before McNemar's criterion (10) for completeness of factor extraction was met. The highest coefficient in each column of the correlation matrix was used as the estimate of communality of the corresponding variable.

The eight reference axes were rotated by means of the Zimmerman graphic, orthogonal system of rotation (30). The rotations were guided by the three criteria: positive manifold, simple structure, and psychological meaningfulness. Thirty-three rotations yielded an orthogonal solution with seven interpretable factors and one residual.

4. Results

a) Interpretation of Factors

The unrotated centroid factor loadings and communalities are presented in Table 3. The final rotated factor matrix is presented in Table 4. From the mean squared factor loadings at the bottom of the columns in Table 4 it may be seen that the eight factors extracted account for approximately 42% of the total variance in judgments.

TABLE 3

Unrotated Centroid Factor Loadings and Communalities*

	A	B	C	D	E	F	G	H	h^2
1. pleasant-unpleasant	55	35	-06	13	-07	-24	13	-10	5349
2. repeated-varied	24	16	24	02	20	15	04	08	2117
3. smooth-rough	22	58	02	15	08	-24	-06	-07	4802
4. active-passive	07	-05	29	27	-05	23	10	13	2467
5. beautiful-ugly	38	56	05	12	-16	-18	15	-16	5810
6. definite-uncertain	32	14	36	26	13	29	14	02	4402
7. low-high	52	-45	-28	07	09	-15	07	-06	5953
8. powerful-weak	43	-49	32	-03	-08	18	03	-10	5780
9. steady-fluttering	29	03	28	21	15	16	02	-24	3136
10. soft-loud	10	41	-37	23	07	-29	05	11	4715
11. full-empty	51	-28	29	-06	-13	-06	07	04	4532
12. good-bad	50	39	16	-10	-16	-12	10	-10	4977
13. rumbling-whining	60	-48	-19	09	06	-07	05	05	6481
14. solid-hollow	39	-08	22	14	-09	-03	12	-08	2563
15. clear-hazy	32	17	46	-10	03	15	-12	-07	3956
16. calming-exciting	28	13	-32	-26	21	-10	13	-02	3367
17. pleasing-annoying	61	35	-06	13	-17	-07	01	-16	5746
18. large-small	51	-61	05	-09	-08	07	05	-14	6762
19. clean-dirty	13	51	21	-10	-20	-02	03	02	3728
20. resting-busy	09	21	-42	-02	12	02	-04	-15	2679
21. dull-sharp	42	-47	-39	-11	08	-08	-02	04	5763
22. deep-shallow	54	-45	-01	-13	-08	-03	-06	-04	5236
23. gliding-scraping	30	29	-07	28	03	02	-25	-08	3276
24. familiar-strange	45	16	15	21	08	16	10	09	3448
25. soft-hard	21	35	-36	02	-07	-07	-13	15	3458
26. heavy-light	48	-69	-01	-11	-03	04	10	-12	7456
27. wet-dry	24	-13	-12	33	-11	09	-07	14	2425
28. safe-dangerous	26	42	-18	-32	-07	08	17	12	4334
29. concentrated-diffuse	21	01	42	-10	20	-04	-10	-04	2838
30. pushing-pulling	10	-01	-06	-15	08	-09	10	12	0751
31. labored-easy	09	-58	09	-21	15	-12	14	-07	4581
32. dark-bright	15	-66	-15	14	14	-02	-07	-10	5351
33. even-uneven	29	31	35	09	23	08	-06	10	3837
34. loose-tight	27	04	-40	10	-27	20	-18	-15	4123
35. relaxed-tense	38	24	-43	-09	-25	19	-20	-08	5400
36. colorful-colorless	29	16	22	05	-25	-16	-15	17	3001
37. hot-cold	04	17	30	-22	-05	-17	-17	-02	2296
38. rich-thin	49	-17	06	-09	-15	-10	-26	17	4097
39. obvious-subtle	22	06	34	-24	17	03	-02	11	2675
40. wide-narrow	54	-50	-08	-09	-03	06	-12	-01	5751
41. deliberate-careless	36	-07	42	-06	13	-10	-08	21	3919
42. happy-sad	13	50	14	-11	-19	-03	09	17	3726
43. gentle-violent	25	50	-40	08	-02	09	14	14	5266
44. mild-intense	28	39	-43	-19	04	03	05	10	4665
45. rounded-angular	41	-13	-17	19	02	04	-18	-03	2853
46. slow-fast	37	-41	-31	-19	10	11	11	-14	4910
47. rugged-delicate	36	-56	19	-12	-02	-05	-07	-12	5159
48. simple-complex	14	25	-17	-28	20	16	11	12	2815
49. green-red	07	-03	-28	11	-07	12	10	18	1580
50. masculine-feminine	46	-56	11	07	08	-09	-10	-10	5767

* Decimal points have been omitted.

TABLE 4

Final Rotated Factor Matrix*

	I	II	III	IV	V	VI	VII	VIII	h^2
1. pleasant-unpleasant	16	60	07	23	07	25	16	-01	5365
2. repeated-varied	01	05	41	16	-06	12	06	05	2204
3. smooth-rough	-24	54	12	17	06	18	11	20	4806
4. active-passive	-01	-15	27	-11	-06	30	14	-15	2433
5. beautiful-ugly	-11	67	13	17	07	22	12	-12	5889
6. definite-uncertain	03	04	52	06	-06	39	04	-10	4438
7. low-high	71	05	-16	14	02	18	-02	12	5994
8. powerful-weak	60	-09	35	-22	-08	06	-01	-17	5780
9. steady-fluttering	13	15	40	-07	-04	30	-16	01	3216
10. soft-loud	-19	32	-28	33	12	25	16	21	4724
11. full-empty	53	13	27	-09	-13	03	22	-12	4594
12. good-bad	09	59	28	16	05	02	18	-14	5151
13. rumbling-whining	76	-02	-04	12	05	21	09	09	6568
14. solid-hollow	30	20	21	-07	-09	22	09	-12	2580
15. clear-hazy	06	21	58	-08	-01	-03	06	-01	3952
16. calming-exciting	18	20	-06	48	05	-12	-07	10	3382
17. pleasing-annoying	19	58	17	15	27	25	12	-06	5773
18. large-small	79	-07	12	-11	-01	01	-04	-13	6742
19. clean-dirty	-27	40	25	07	06	-06	21	-16	3772
20. resting-busy	-02	16	-15	29	28	03	-20	13	2688
21. dull-sharp	67	-09	-20	19	13	-03	00	14	5705
22. deep-shallow	71	04	09	-04	06	-05	08	-01	5280
23. gliding-scraping	-02	29	15	01	30	29	04	22	3312
24. familiar-strange	14	14	37	18	05	35	15	-03	3569
25. soft-hard	-07	24	-12	28	36	04	21	13	3475
26. heavy-light	84	-13	04	-06	-06	00	-08	-11	7498
27. wet-dry	21	-07	-03	-04	21	34	18	02	2440
28. safe-dangerous	-06	27	12	48	20	-17	14	-17	4387
29. concentrated-diffuse	11	12	43	-07	-21	-06	03	16	2905
30. pushing-pulling	10	02	-02	21	-08	-09	09	03	0784
31. labored-easy	50	-19	-04	-05	-34	-17	-13	01	4517
32. dark-bright	57	-29	-16	-14	-04	14	-17	17	5332
33. even-uneven	-08	17	51	12	-06	17	14	16	3875
34. loose-tight	19	13	-11	02	57	12	-04	-08	4128
35. relaxed-tense	14	26	-02	20	64	-03	03	-06	5426
36. colorful-colorless	06	28	17	-13	06	03	41	00	3004
37. hot-cold	-08	24	22	-13	-09	-26	13	08	2283
38. rich-thin	45	13	16	-08	17	-07	34	13	4177
39. obvious-subtle	09	06	43	10	-16	-16	12	07	2771
40. wide-narrow	73	-07	10	-02	15	-01	05	05	5758

(Continued on following page)

TABLE 4 (Continued)

	I	II	III	IV	V	VI	VII	VIII	h^2
41. deliberate-careless	25	08	41	-03	-21	-01	30	16	3977
42. happy-sad	-26	33	20	18	06	-06	31	-16	3778
43. gentle-violent	-15	25	-05	51	34	20	14	-05	5253
44. mild-intense	-02	25	-05	53	33	-06	08	03	4661
45. rounded-angular	36	07	04	02	26	23	04	17	2875
46. slow-fast	60	-09	-06	23	11	-05	-21	-04	4849
47. rugged-delicate	65	-05	15	-22	-12	-08	-02	01	5172
48. simple-complex	-04	02	15	48	11	-14	-01	00	2867
49. green-red	07	-13	-14	20	18	16	11	-08	1579
50. masculine-feminine	70	-03	11	-18	-09	11	-01	15	5782

<u>Mean Absolute Factor Loading</u>

.286	.195	.193	.168	.147	.138	.121	.097

<u>Mean Squared Factor Loading</u>

.148	.064	.058	.045	.039	.029	.022	.013

* Decimal points have been omitted.

The task of interpreting the extracted factors, i.e., identifying them by name, is somewhat facilitated because of the nature of the variables involved. A cluster of semantic scales, highly loaded on a given factor, usually leaves little doubt as to the dimension of semantic space which that factor represents. The generic term which will embrace the majority of the scale-names found to be highly loaded on a given factor is usually taken to identify that particular factor. However, in interpreting factors, it is necessary to go beyond the given data (i.e., quantitative factor loadings) and to rationally conceive of a proper semantic label for the mathematical dimensions. Most factor analysts recognize this general subjective interpretiveness which is involved in the identification of factors.

It will also be apparent in identifying the factors below that there is a differential clarity of loading patterns and consequently a differential ease with which the factors may be interpreted. Some factors are readily interpretable and clearly represent identifiable dimensions of a semantic space. Other factors are not so easy to interpret and thus require an extension of supposition and imagination for their identification.

The meaning of the first seven factors may be interpreted from the factor loadings presented in Table 4 as follows (scales are identified by number and name):

I. <u>Potency</u>

26	heavy-light	.84
18	large-small	.79
13	rumbling-whining	.76
40	wide-narrow	.73
7	low-high	.71

This is clearly a potency, size-weight factor. Other highly loaded scales on this factor are: <u>deep-shallow</u>, <u>masculine-feminine</u>, dull-sharp, rugged-delicate, slow-fast, and powerful-weak. This factor accounts for approximately 36% of the total common variance accounted for by all eight factors extracted.

II. Aesthetic-Evaluative

5	beautiful-ugly	.67
1	pleasant-unpleasant	.60
12	good-bad	.59
17	pleasing-annoying	.58
3	smooth-rough	.54

This is the well-defined evaluative dimension which seems to be a rather persistent characteristic of our culture. Other scales with high loadings on this factor are: clean-dirty, happy-sad, and soft-loud. This factor accounts for approximately 14% of the variance accounted for by the eight factors extracted.

III. Clarity

15	clear-hazy	.58
6	definite-uncertain	.52
33	even-uneven	.51
29	concentrated-diffuse	.43
39	obvious-subtle	.43

This appears to be a factor specifically related to the clarity or definiteness of the signal to be perceived. It appears to reflect a sort of "confidence level" upon which the sonar operator relies to decide whether he has picked out a coherent noise signal from a background of noise. It seems to indicate a type of figure-ground differentiation process which must be operative before the perception of these complex auditory stimuli can be accepted with a sufficient degree of confidence to warrant basing overt behavior upon them. In psychophysical experimentation, this factor would be markedly involved in studies of masked auditory thresholds. Other scales with relatively high loadings on this factor are: deliberate-careless, repeated-varied, and steady-fluttering. This factor accounts for approximately 13% of the total variance accounted for by this analysis.

IV. Security

44	mild-intense	.53
43	gentle-violent	.51
16	calming-exciting	.48
28	safe-dangerous	.48
48	simple-complex	.48

This factor appears to reflect rather specifically the training in denotative significances which is common to the population of subjects used in this study. The threat to personal security which constantly attends undersea warfare seems to have generated this factor as a major judgmental dimension in the semantic space of sonarmen. This factor represents 11% of variance accounted for.

V. Relaxation

35	relaxed-tense	.64
34	loose-tight	.57
25	soft-hard	.36
43	gentle-violent	.34
44	mild-intense	.33

This factor may be related to the motor components of "listening." It possibly involves the kinesthetic and proprioceptive feedback which presumably contributes to the surrogate (mediating) processes underlying connotative and denotative meanings. It may be hypothesized that, in the final analysis, the psychophysiological tension- or relaxation-producing qualities of sounds are associated with their past conditionings to drive producing or drive reducing situations, respectively. This factor represents 10% of variance accounted for.

VI. Detection

6	definite-uncertain	.39
24	familiar-strange	.35
27	wet-dry	.34
4	active-passive	.30
9	steady-fluttering	.30

The three leading scales on this factor suggest that this represents the denotative confabulation of a connotative dimension which might be labeled "activity." In terms of the task required of the sonarman, this factor represents the subjective interpretation given to the detection of a ship sound (or "activity") somewhere in the sea around him. The operator hears a definite signal through the background of noise. This signal is recognized as one of the familiar sounds the sonar operator has been trained to respond to. The sound is wet, since it is transmitted through the water to his hydraphone. These meanings assigned to the general perception of activity constitute the basis for the judgment "detection" or "contact." This factor represents 7% of the variance accounted for.

VII. Mood

36	colorful-colorless	.41
38	rich-thin	.34
42	happy-sad	.31
41	deliberate-careless	.30
11	full-empty	.22

This, the last of the interpretable factors, is somewhat difficult to make psychologically meaningful. Considering the five most highly loaded scales, it appears as if this factor represents a type of sensualism or experience of bodily pleasure. It may be proposed that certain sounds appear capable of enducing certain moods within the experiencing organism, and this factor reflects that dimension of semantic space. This factor represents only 5% of the total variance accounted for.

b) Characterization of Sounds

The twenty stimuli were arranged in rank order for each factor in terms of their mean scale value on the five most highly loaded scales for any given factor. For example, scales 26, 18, 13, 40, and 7 were picked as the five most highly loaded scales on Factor I. The mean scale value for each of the twenty stimuli (averaged over the five scales) was calculated and the stimuli were rank ordered in terms of these values. In this manner it is possible to isolate those stimuli which are most representative of the extreme polarities representing the factors. The five highest and lowest ranking stimuli for each factor are presented in Table 5.

On Factor I it appears as if the Type C stimuli were most characteristic of the positive end of the continuum, while Type A and B stimuli clustered at the negative end of the dimension. Thus, Type C stimuli may be characterized as heavy, large, rumbling, wide and low; while Types A and B stimuli may be described as light, small, whining, narrow, and high. These distinctions agree quite well with those currently employed by the Navy to characterize these types of vessels.

No consistent relationships were immediately apparent on Factor II. A Type A, two B's, a C and a D stood high on this factor, while two A's, a B, a C and a D clustered at the low end. This result is not too surprising, however, since an aesthetic-evaluative response is usually rather unique to the individual making it and quite frequently reflects the specific experiential history of that subject.

Factor III (Clarity) clearly differentiated between Types A and D and Types B and C stimuli. Highest ranking on this factor are the class B and C stimuli. These sounds may be described, therefore, as clear, definite, even, concentrated, and obvious. Stimuli of the A and D type, however, are, on the whole, hazy, uncertain, uneven, diffuse, and subtle. A glance at Figures 8 and 9 reveals that class B stimuli are characterized by the presence of rather dominant frequency bands and class C stimuli are characterized by rather obvious recurrent intensity patterns. Figures 7 and 10 indicate, however, that Type A stimuli are very close to the spectrum for white noise and Type D stimuli provide very little energy above 500 cycles to aid in identification. The fact that Type B and C stimuli are judged "clearer" than Type A and D stimuli would seem to be in accord with the physical nature of these sounds.

Factor IV (Security) appears to reflect the denotative significance which has come to be associated with certain sounds because of the specific training and experience to which the sonar operator is subjected. Type C stimuli appear to be the least threatening to the sonarman, while, conversely, A, B, and possibly D are the most threatening. Thus, Type C stimuli may be characterized as mild, gentle, calming, safe, and simple; while the other three stimuli are intense, violent, exciting, dangerous, and complex. In terms of the realities of undersea warfare, it is the Type C sounds which are usually produced by the least dangerous enemy vessels, while it is the enemy vessels producing sounds of Type A, B, and D which are usually the most heavily armed and serve to protect the Type C vessels.

Although no consistent relation is immediately apparent on Factor V (Relaxation), it may be possible to propose that it is the Type B sounds which are most relaxed, loose, soft, gentle, and mild; while it is the Type D stimuli which are tense, tight, hard, violent, and intense. An understanding of these interpretations may be gained by looking at Figures 8 and 10. Figure 8 (Type B stimuli) shows that these sounds are composed of fairly specific bands of frequencies. Such a composition tends to move the sound away from "noise" toward the make-up of a musical cord. Also, these class B sounds have been characterized by the Navy as having a "putt-putt" quality, with light beats. All of these attributes would not seem to belong to that class of stimuli which have the quality of producing psychophysiological tension.

On the other hand, Figure 10 reveals that these stimuli (Type D) have the majority of their energy concentrated below 1000 cycles, thus producing a rather specific, intense, tight concentration of sound.

The ordering of sounds on Factor VI is rather difficult to interpret. It appears as if there is a rather clear differentiation being made between Type A and B stimuli on the one hand, and Type C and D stimuli on the other. It is possible to characterize stimuli of the A and B classes as definite, familiar, wet, active, and steady; while those stimuli of the C and D classes are uncertain, strange, dry, passive, and fluttering. However, in view of the previous interpretation of sound arrangements on Factor III, it does not seem consistent the label Type C stimuli as uncertain. Perhaps the interpretation of the meaning of Factor VI is somewhat off the mark. The author is, at present, unable to harmonize these findings.

Factor VII (Mood) clearly splits the sounds into two groups: Type C and D stimuli, and Type A and B stimuli. Stimuli of the C and D class may be labeled as colorful, rich, happy, deliberate, and full. Stimuli of the A and B class may be labeled as colorless, thin, sad, careless, and empty. The "high mood" sounds (looking at the spectrograms in Figures 9 and 10) seem to be characterized either by a dominant, slow, rhythmic pattern (Type C) or by a concentration of energy to a restricted portion of the energy spectrum (Type D). The "low mood" sounds, on the other hand, appear to present either a random, "white noise" spectrogram (Type A) or seem to approach this condition (Type B).

TABLE 5

Highest and Lowest Ranking Stimuli on Each Factor

		Highest Ranking					Lowest Ranking				
Factor I (Potency)	#	3	13	7	11	20	16	2	9	19	10
	Type	C	B	C	C	A	A	B	A	B	B
Factor II (Aesthetic Evaluative)	#	4	19	15	6	9	20	10	3	1	8
	Type	D	B	C	B	A	A	B	C	A	D
Factor III (Clarity)	#	6	19	13	3	7	12	20	8	5	16
	Type	B	B	B	C	C	D	A	D	A	A
Factor IV (Security)	#	15	9	7	11	19	14	6	20	10	16
	Type	C	A	C	C	B	D	B	A	B	A
Factor V (Relaxation)	#	19	9	13	15	12	6	20	14	3	8
	Type	B	A	B	C	D	B	A	D	C	D
Factor VI (Detection)	#	5	19	9	15	13	4	3	18	8	12
	Type	A	B	A	C	B	D	C	C	D	D
Factor VII (Mood)	#	7	3	17	11	4	10	5	6	16	20
	Type	C	C	D	C	D	B	A	B	A	A

III. DISCUSSION

A. The Effects of Training

In interpreting the meaning of the factors presented in the preceding section, it was necessary, on occasion, to mention the possible confounding of connotative meanings with denotative significances, due primarily to the nature of the stimuli employed in this study and to the nature of the population used. Also, it should be remembered that the testing took place in a situation which very closely simulated the actual "on duty" conditions of the sonar operator.

The results of this study provide us with a picture of the semantic space which characterizes the "sonar culture." The structure of this space, it is assumed, is the end result of the modification of the general population semantic space which characterizes naive subjects and which, presumably, each sonarman brings with him when he enters training school to become a sonar operator. It would be consistent to propose, therefore, that the structure presented above (in its final rotated form) represents the modifying influences which training in denotative significances can exert upon a general semantic frame of reference. The rotation process has clarified the denotations which sonar training and experience have attached to connotative dimensions. For a clearer picture of these "pure" connotative dimensions, some additional research is needed, similar to that presented above, but utilizing a population of naive subjects.

For some indication of what the general population frame of reference might be, one may look at the unrotated factor matrix presented in Table 3. By the very nature of Thurstone's centroid method of factor extraction, Centroid I is an approximation to the dimension which will account for most of the variance. Subsequently, Centroid II is an approximation to the dimension which will account for most of the residual variance, and so on through the extraction of the remainder of the centroids. With this in mind, one may examine Table 3. Only the positive ends of the scales will be discussed, as if they had been rotated to positive manifold.

Centroid A appears to be most closely related to rotated Factor II. The five most highly loaded scales on it are: pleasing, rumbling, pleasant, deep, and wide. Characteristic of the indistinct patterns enmeshed in the unrotated factor matrix, this centroid appears to be an evaluative-aesthetic dimension, somewhat combined with scales related to the potency dimension. Other scales highly loaded on this centroid are: low, full, large, and good.

It is assumed that this unrotated centroid is accounting for the major source of variance in the population, before rotation superimposes variance due to certain denotative significances. It may be proposed, therefore, that the major judgmental dimension of the semantic space of the general population is an evaluative-aesthetic one.

Centroid B might be interpreted as representing a dimension of ponderance, quite similar to the rotated Factor I. Scales like heavy, dull, large, smooth, and labored are most highly loaded on this centroid.

Centroid C appears to be a dimension of activity, somewhat less contaminated with denotative significances than the rotated

Factor VI. This centroid is most highly loaded with such scales as: clear, relaxed, mild, resting, and concentrated.

After Centroid G, the mean loadings on the remaining centroids drop to a fairly stable minimum value, so they shall not be considered in this discussion.

The relation of the foregoing Centroid interpretations to Osgood's findings are quite interesting. In his factor analysis of semantic space, he employed a sample of the general population and had them rate a random selection of concepts on the Semantic Differential. His analysis of the scale intercorrelations yielded three interpretable factors which accounted for approximately 50% of the total variance in judgments. These three factors were: "evaluation," "potency," and "activity." "Evaluation" accounted for the largest part of the variance, with the remainder being almost equally divided between "potency" and "activity." Osgood contends that these three dimensions represent the major structure of the semantic space of the general population. A striking thing to note in the results presented above is that even with such a limited and unusual set of concepts such as sonar sounds, the first three factors evident in the unrotated matrix may be identified as evaluation, potency, and activity.

From our results, it appears as if this unrotated structure tends to persist through the period of training as a sonarman, but becomes confounded with the effects of the training. It would follow from this that if a naive population were tested using the procedure of this study, the rotation process would not tend to change the structure, but would rather clarify it along the lines evident in the Centroid A-B-C patterns discussed above and the three-factor solution reported by Osgood.

B. <u>Relation of Factors to Previous Studies</u>

The attempt to find identities or similarities between factors isolated in different studies by different investigators utilizing different stimuli and different populations is a somewhat precarious undertaking. The correspondence between the findings of this study and those of Osgood were facilitated by the identity of technique employed in both investigations. In comparing these results with those of other investigators, however, one is hampered by a marked lack of comparable methodology.

In reviewing the studies presented in Section 2 of the Introduction to this paper, some basis for comparison between our findings and those of Fischer-Jorgenson and Lichte may be found. Both of these investigators were attempting to study the "meaning" of sounds and sound combinations. Neither of them, however, made use of the factor analytic technique to discover the major dimensions of meaning along which their sounds might vary. Instead, each merely selected one or two psychological scales upon which to have their sounds rated and then studied the positions of various sounds within this restricted space. There was no guarantee that the dimensions they selected to employ were statistically independent and represented orthogonal factors in semantic space. Fortunately, however, it appears that these investigators did pick dimensions which, according to the findings presented above, represent major sources of variance in meaning.

Fischer-Jorgenson employed two scales in her study: bright-dark and less volume-more volume. These appear to be closely related to Factor I (Potency), although bright-dark has a fairly substantial loading on Factor II (Aesthetic-Evaluative).

Lichte made use of the three dimensions of brightness, roughness, and fullness. As stated above, brightness appears to be related primarily to Factor I, with some possible relation apparent with Factor II. Roughness is clearly related to Factor II (when considered as a dimension of smoothness), but has some relation to Factor I also. Fullness is most highly loaded on Factor I, but also indicates some relationship to Factors III (Clarity) and VII (Mood).

Thus, it appears that most of the dimensions selected by these previous investigators represent primarily two dimensions in semantic space: potency and aesthetic-evaluative. Perhaps this may be taken as further corroborative evidence for the existence of a general semantic frame of reference, as is postulated by Osgood.

C. Application of Results

Utilizing the seven dimensions revealed by the factor analysis, it may be possible to modify sonar school curricula so that new sonar operators would be explicitly trained in terms of these variables. By providing a common "meaning" for diverse stimuli (i.e., various sonar recordings could be judged in terms of a relatively few basic dimensions) the amount of independent information that a sonar operator has to handle would be materially reduced. With ordinary learning, an increase in items disproportionately increases the difficulty of retention, while, if the items can be mediated by a common concept, an increase in items does not necessarily increase difficulty.

Another possibility would be to utilize the results of a comparison between sonar operators' data and data obtained from a sample of the general population. From an examination of such information, it should be possible to isolate crucial points of shift on certain scales which highly differentiate the two populations. That is, it may be possible to determine on which dimensions and in what direction training in denotative significances tends to modify connotative meanings. If these crucial "shift-points" could be isolated, they would provide helpful areas of concentration to facilitate the training procedure.

Finally, now that factor analysis has revealed a minimal number of descriptive dimensions having maximal differentiating power, it would be an interesting extension of the research (and, indeed, a very meaningful one) to investigate what changes in the composition of the physical stimulus consistently accompany changes in the "meaning" of those stimuli. If consistent relationships can be found, it may be possible to enhance the discriminability of various stimuli which lie close together in "semantic space" (as defined by the dimensions derived from the factor analysis) by equipment that is especially engineered so as to modify the physical components of the stimuli in a direction <u>away</u> from psychological similarity.

D. <u>Suggestions for Further Research</u>

Two suggestions have already been presented; namely: a comparison of sonar operators with a sample of the general population and a search for concomitant variation between components of the physical stimulus and judgments in semantic space. An outline of additional possibilities for investigation might include:

1) Having the operators (and/or a sample of the general population) rate visual stimuli (oscilloscope tracings) rather than auditory stimuli to determine the differences and correspondences in semantic structure.

2) Having "good" and "poor" operators perform the task and then compare the groups for differences.

3) Add a "difficult-easy" category for each rating to be made. This would provide information highly useful in the training procedure. The majority of effort could be directed toward training in those responses which are most difficult but also most differentiating.

4) Extend the range of stimuli to sounds from sources other than ship screws. That is, include among the stimuli-to-be-rated sounds such as: torpedo sounds, depth charges, bell bouys, surf noises, and sounds of biological origin such as shrimp, porpoise, and croaker.

IV. SUMMARY AND CONCLUSIONS

A factor analytic study of the meanings of passive sonar sounds was undertaken for the purpose of deriving a limited number of descriptive dimensions which have maximum differentiating power. The study was an attempt to structure explicitly the implicit frame of reference within which the passive-sonar operator makes the discriminal responses underlying sonar recognition and detection.

The procedure was divided into three sequential phases: 1) the compilation of a series of descriptive scales upon which sonar sounds could be assigned quantitative values; 2) the determination of the meaningfulness of this task by an analysis of the consistency with which an experimental population assigned certain sonar sounds to certain positions on these scales; and 3) a factor analysis of the intercorrelations between scales to derive a limited number of general dimensions of meaning having maximal differentiating power.

In Experiment #1, a series of 50 seven-point scales was compiled, each scale being defined by a pair of polar-opposite adjectives. The adjectives were obtained from the following sources: 1) A preliminary study run on 26 college students at the University of Illinois wherein the subjects were asked to write as many descriptive words as they felt were applicable to describe various passive sonar recordings presented to them; 2) A list of scales being used at the University of Illinois in a study of aesthetic judgments; 3) Rational analysis of the sensory inputs of the human organism; 4) The list of high ranking helpful sonar recognition cues presented in an NEL report on ship classification teaching methods; and 5) The list of scales used by Osgood in his study of meaning.

In Experiment #2, sixteen male subjects rated four passive sonar sounds on the 50 scales compiled from Experiment #1. A test-retest paradigm was employed, the inter-test interval being five days. A new statistical test of consistency was developed to test the null hypothesis that subjects make their ratings by chance against the alternative hypothesis that subjects are consistent in their ratings.

It was found that it is possible to reject the null hypothesis at or beyond the 1 per cent level of confidence for all 50 scales.

In Experiment #3, 50 naval sonarmen (median sonar experience of one year) rated 20 different passive sonar sounds on the 50 scales derived from Experiment #1. The intercorrelations between scales (calculated over both subjects and sounds) were factor analyzed by the Thurstone complete centroid method. Eight factors were extracted from the data. The factors were rotated by the graphic method to meet the criteria of positive manifold, simple structure, and psychological meaningfulness. The final rotated matrix presented seven interpretable orthogonal factors and one residual.

In interpreting the factors, the following designations were assigned to them: Factor I - Potency; Factor II - Aesthetic-Evaluative; Factor III - Clarity; Factor IV - Security; Factor V - Relaxation; Factor VI - Detection; Factor VII - Mood.

The twenty sounds were arranged in rank order for each factor in terms of their mean scale value on the five most highly loaded scales for any given factor. The five highest ranking and the five lowest ranking stimuli on each factor were discussed in the light of the physical nature of the stimuli and their denotative significance.

The confounding effect that denotative training may have upon connotative meaning was discussed. The relation of the factors isolated in this study to findings of previous studies was examined in the light of this discussion. Possible application of our results and suggestions for further research along these same lines were also presented.

V. BIBLIOGRAPHY

1. Bruner, J. F. & Goodman, C. C. Value and need as organizing factors in perception. J. abnorm. soc. Psychol., 1947, 42, 33-44.

2. Bruner, J. F. & Postman, L. Symbolic value as an organizing factor in perception. J. soc. Psychol., 1948, 27, 203-8.

3. Fischer-Jorgenson, Eli. Approaches to a perceptual description of speech sounds. January 1951. (Speech given in Oslo, Norway.)

4. Gagné, R. M. & Baker, K. E. Stimulus pre-differentiation as a factor in transfer of training. J. exp. Psychol., 1950, 40, 439-51.

5. Karlin, J. E. A factorial study of auditory function. Psychometrika, 1942, 7, 251-279.

6. Karwoski, T. F. & Odbert, H. S. Color-music. Psychol. Monogr., 1938, 50, whole #222.

7. Lawrence, D. H. Acquired distinctiveness of cues: II, Selective association in a constant stimulus situation. J. exp. Psychol., 1950, 40, 175-188.

8. Lichte, W. H. Attributes of complex tones. J. exp. Psychol., 1941, 28, 455-480.

9. McGinnies, E. Emotionality and perceptual defense. Psychol. Rev., 1949, 56, 244-51.

10. McNemar, Q. On the number of factors. Psychometrika, 1942, 7, 9-18.

11. Mosier, C. I. A psychometric study of meaning. J. soc. Psychol., 1941, 13, 123-140.

12. Neff, W. D. & Thurlow, W. R. Auditory discrimination in sonar operation, in A survey report on human factors in undersea warfare. Washington, D.C.: National Research Council Committee, 1949, pp. 219-230.

13. Odbert, H. S., Karwoski, T. F. & Eckerson, H.B. Studies in synesthetic thinking: I. Musical and verbal associations of color and mood. J. gen. Psychol., 1942, 26, 153-173.

14. Osgood, C. E. The nature and measurement of meaning. Psychol. Bull., 1952, 49, 197-237.

15. Osgood, C. E. & Suci, G. J. A measure of relation determined by both mean difference and profile information. Psychol. Bull., 1952, 49, 251-262.

16. Osgood, C. E. & Suci, George J. Factor analysis of meaning, J. exp. Psychol., in press.

17. Postman, L., Bruner, J. S. & McGinnies, E. Personal values as selective factors in perception. J. abnorm. soc. Psychol., 1948, 43, 142-154.

18. Reichard, G. A., Jackobson, R., & Werth, E. Language and synesthesia. Word, 1949, 5, 224-233.

19. Riggs, L. A. & Karwoski, T. F. Synesthesia. Brit. J. Psychol., 1934, 25, 29-41.

20. Salmon, V. Imagery in describing tone quality. J. acoust. Soc. Amer., 1947, 19, 731.

21. Small, A. M. Underwater sounds of biological origin. J. acoust. Soc. Amer., 1948, 20, 225.

22. Solomon, L. N. Reliability of the connotative associations to passive sonar sounds using a new statistical test of consistency. San Diego: U.S. Navy Electronics Laboratory Report #443, 1953.

23. Thorndike, E. L. The association of certain sounds with pleasant and unpleasant meanings. Psychol. Rev., 1945, 52, 143-149.

24. Thurstone, L. L. Multiple-factor analysis. Chicago: University of Chicago Press, 1947.

25. Torgerson, W. S. Multidimensional scaling: I. Theory and method. Psychometrika, 1952, 17, 401-419.

26. Walker, Helen M. & Lev, Joseph. Statistical Inference. New York: Henry Holt, 1953, pp. 441-443.

27. Wheeler, R. H. & Cutsforth, T. D. Synesthesia and meaning. Amer. J. Psychol., 1922, 33, 361-384.

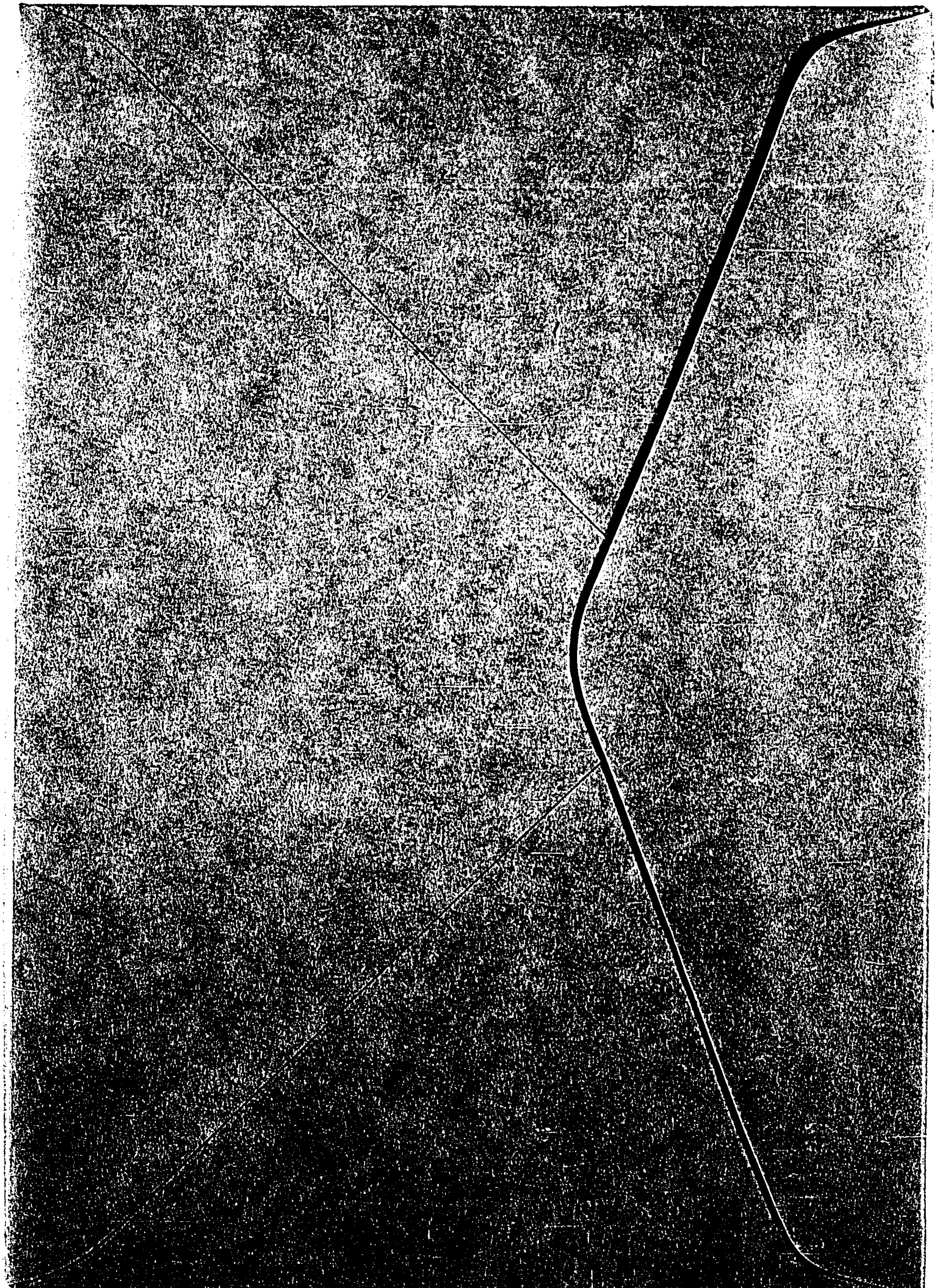
28. Young, G. & Householder, A. S. Discussion of a set of points in terms of their mutual distances. Psychometrika, 1938, 3, 19-22.

29. Zigler, M. J. Tone shapes. J. gen. Psychol., 1930, 3, 277.

30. Zimmerman, W. S. A simple graphical method for orthogonal rotation of axes. Psychometrika, 1946, 11, 51-55.

31. An experiment in ship classification teaching methods. San Diego: U. S. Navy Electronics Laboratory, Contract No. 86811, June 1952.

VI. APPENDIX - THE CORRELATION MATRIX



	1	2	3	4	5	6	7	8	9	10
1	55	13	46	02-	52	16	18	02	12	31
2	13	29	17	09	11	28	02-	11	20	02-
3	46	17	49	10-	49	08	14-	22-	10	37
4	02-	09	10-	32	04	32	02-	18	15	10-
5	52	11	49	04	54	18	06-	10-	13	32
6	16	28	08	32	18	35	02	21	35	03-
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V I T A

Lawrence Norval Solomon was born on April 23, 1929, in Los Angeles, California. He moved to San Diego, California, in 1935 and graduated from Herbert Hoover Senior High School in 1946. He then entered San Diego State College and received the degree of Bachelor of Arts, with Honors and Distinction in Psychology, from that institution in June, 1950. He entered the Graduate College of the University of Illinois in September of that year as a University Fellow in Psychology. In February, 1951, he relinquished his Fellowship in favor of a Research Assistantship which he held until December, 1952. From that date until June, 1953, he held a U. S. Public Health Fellowship in Psychology. During the summer months of 1951, 1952, and 1953 he worked as an experimental and physiological psychologist at the U. S. Navy Electronics Laboratory in San Diego. Publications are: 1) Mowrer, O. H. & Solomon, L. N. Contiguity vs. drive reduction in fear conditioning: I. The proximity and abruptness of drive reduction. Amer. J. Psychol., 1954, 67, 15-25. 2) Solomon, L. N. Reliability of connotative associations to passive sonar sounds using a new statistical test of consistency. USNEL Report #443, 1953.