MULTIDIMENSIONAL PSYCHOPHYSICS AND

VERBAL ASSOCIATIONS

by
William S. Ray

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CHAPTER I

INTRODUCTION AND BACKGROUND

For many years psychologists have directed an appreciable portion of their efforts toward the achievement of objectivity and scientific status for their profession. The importance of developing quantitative methods as a means to that end has gained wide acceptance, and measurement has become a vital concern of psychologists. An impressive amount of discussion and research has been invested in attempts to establish adequate scales for the measurement of psychological phenomena and characteristics.

The quest for satisfactory quantitative methods has been beset with many problems. No problem has been more important or more difficult than that of establishing the dimensionality of a given domain of research. When the domain is a relatively new one, unexplored and uncharted, as is so often the case in psychology, the difficulties are especially acute. Before measurement along any particular dimensions can take place and before experimental variables can be chosen properly, we must have knowledge of the existence of and nature of these dimensions and variables and their interrelationships.

The problem of determining the basic dimensions of a given domain first arose in connection with the testing of mental abilities. The methods of factor analysis were evolved to provide a solution to the problem (11,13). A similar problem has been encountered in modern psychophysical research. Only recently have steps been taken which

point toward the eventual solution of the problem of psychological dimensionality of stimulus materials other than simple sensory attributes. The most recent proposal has been made for a solution based on the conversion of psychophysical data to estimates of correlations and the use of factor analysis. The present study follows upon that proposal in applying the methods of multiple-factor analysis to the determination of the dimensionality of psychophysical data consisting of judgments of complex verbal stimuli.

The dimensionality of mental tests. Within the mental-test movement the problem of dimensionality arose in connection with the observed interrelationships among mental tests of different kinds. It soon became evident that an almost countless number of different kinds of mental tests could be formulated. The high intercorrelations among some of these tests indicated that some of them measured common psychological traits. Poor economy resulted from the use of several tests to measure the same attribute when one test would do as well. The fact that many of these intercorrelations were low indicated that not all of the tests measured the same trait. Quite logically the question was raised as to what were the basic or the fundamental dimensions of mental ability. If one had knowledge of the basic or the fundamental dimensions then a single test might be chosen to represent each one of these dimensions and a considerable degree of scientific parsimony would be effected. The practice of combining scores from several tests into a single score posed another problem. If the tests were uncorrelated, i.e. if they measured

different, independent attributes, then a single number could not be used to make an unequivocal statement regarding the position of a person on a linear scale. Separate scores, each of which designated an appropriate position on one of the basic dimensions, were needed for the most meaningful and efficient description.

Factor analysis in a number of different forms has provided a widely accepted method for determining the dimensionality of a matrix of intercorrelations among tests. One of the early achievements in the use of factor analysis concerned establishing the nature of mental ability. Many attempts had been made to measure "intelligence" conceived of as a unitary ability or a single basic dimension (11). Results of extensive factor-analysis studies have revealed not one dimension but several (16). The resulting concept of "primary mental abilities" has gradually replaced the older, inadequate concept of "intelligence" (13).

Of the several alternative methods of factor analysis which have been developed, the methods of multiple-factor analysis formulated by Thurstone (14) have been used the most frequently in America and have been adopted for the purposes of the present research. The methods of multiple-factor analysis have the advantage of efficiency in the original factoring procedure and of providing a method for establishing psychologically meaningful reference axes as a basis for interpreting the established dimensionality. The methods have been given a rational basis in the mathematics of matrix theory.

The dimensionality problem in psychophysical research. An important event in the history of modern psychophysics has been the development of scaling procedures based upon the method of paired comparisons (12). Thurstone's law of comparative judgment involves a rationale for the scaling of stimuli when comparative judgments are made with respect to some presumed attribute of the objects as specified by the experimenter in his instructions to the subjects. The extensive use which is being made of the method of paired comparisons and the law of comparative judgment in the development of scales for psychological measurement rests upon the assumption of a linear or unidimensional scale. The assumption is made that all subjects make their judgements with respect to the same attribute or along the same continuum.

There is evidence in many instances that the assumption of a linear scale is a poor one and that respondents may very well use a number of continua for their judgments. In most experiments the investigator can do nothing about controlling the situation in order to insure that a single scale is used.

An internal consistency check for a linear scale has been suggested by Gulliksen (5) and may be applied to the matrix of proportions produced by use of the method of paired comparisons. The stimuli are ordered on the scale according to the average magnitude of the proportions for each one. The proportions are then converted to sigma distances as required in the law of comparative judgment. If the system is unidimensional, the distances between adjacent points on the scale should, when added in various combinations, give each of the other entries in the matrix, excepting of course the diagonals.

A simple procedure is to plot the paired entries of each possible pair of columns on a graph. The criterion for linearity is satisfied if each plot is a straight line with a slope of unity. No test of departure from linearity has been given.

When the internal consistency check is not judged to be satisfied, a question must then be raised as to the dimensionality of the system. Young and Householder (17,18) have shown (a) how to determine whether or not the stimuli lie in a real Euclidean space; (b) if they do, how to determine the dimensionality of the space; and (c) how to obtain the projections of the points on an arbitrary orthogonal reference system. It has been shown that the interpoint distances, as given in the sigma values derived from the original proportions, uniquely determine the dimensionality of the space occupied by the set of points representing the stimuli. The methods suit the case of data which are not fallible and which are given in absolute distances. According to the authors the arbitrary reference system may then be rotated to provide meaningful dimensions if criteria for such are available.

There have been at least two investigations in which the dimensionality of the space occupied by the stimuli of a psychophysical experiment was determined.

Richardson (9) established a two-dimensional continuum for a set of nine Munsell colors differing in gray-value and in saturation. It is known that the investigator used a method involving triads, in which the subjects made judgments concerning the relative psychological distance between each possible pair of stimuli. Only an

abstract has been published, however, and the details of the study
are not available.

In the second investigation, concerning the likelihood of war
between various nations, Klingberg (6) established a three-dimensional
system representing the relative friendliness of six nations.

The problem of rotating a set of arbitrary axes to reveal psy-
chologically meaningful dimensions has not been discussed in the
literature except in connection with human traits and other results
of attempted linear measurement. According to Gulliksen (5), cases
of higher dimensionality have not been sufficiently investigated for
any general agreement to have been reached as to the particular axes
to be used.

The methodological approach which begins with the assumptions
of the law of comparative judgment has been discussed in detail by
Torgerson (15) and several extensions of the method have been sug-
gested by him. A scale of comparative distances between all pairs
of stimuli is obtained. In what is described as "the complete method
of triads", the stimuli are presented to the subjects in groups of
three. The subject is instructed to make a judgment of each stimulus
in the triad. The judgment required is of the nature: Stimulus A
is more similar to stimulus B than to stimulus C. From the simi-
larity judgments may be obtained the proportion of times that stimulus
A is judged more similar to stimulus B than to C. From the proportions
sigma distances are derived as in the law of comparative judgment.

Distances between each pair of stimuli are located on a continuum
as distinguished from the usual situation in which the stimuli

themselves are located on a continuum. Torgerson has proposed a least-squares solution for the scale separations. The absence of a true zero point, which is characteristic of all scales based on the law of comparative judgment, means that the comparative distance is an absolute distance minus a constant. The unknown constant must be estimated so that the comparative distances can be converted to absolute distances necessary for the determination of the dimensionality of the space. Torgerson has suggested two practical methods for estimating the constant. The author has also evolved a procedure for determining the dimensionality of the psychological space needed to account for the absolute distances when fallible data are used. Projections on a set of arbitrary axes can be obtained. The origin is located at the centroid of the points representing the stimuli. Torgerson states that the arbitrary reference axes may be rotated to provide meaningful dimensions if criteria for such are available.

The conversion of psychophysical data to estimates of correlation. A proposal has recently been made by Andrews (1) concerning the application of the methods of multiple-factor analysis to estimates of correlation derived by a transformation of the original proportions that may be obtained from certain psychophysical methods and from a method of triads. The rationale for the transformation and the application of factor methods is found in the specification of a set of experimental conditions which makes it reasonable to assume that the proportions, after being transformed, yield estimates of correlation coefficients. The concept that is involved in this

transformation is that proportions are consistent estimates of coefficients of determination, which in turn are squares of correlation coefficients.

In an initial study of the psychophysical problem, Andrews (1) made use of the data of Saffir (10) from the latter's study of nationality preferences. Saffir used as stimuli the names of twenty-five nationality and racial groups. A homogeneous group of one hundred and thirty-three subjects was obtained from classes at the University of Chicago. Each subject was instructed to indicate a preference for a member of each one of all of the possible pairs of names. The data were summarized in a matrix which gave the proportion of the subjects which preferred each nationality to each one of the others. In order to factor analyze the matrix, the proportions were converted by Andrews to estimates of correlation coefficients.

The conversion of the proportions to estimates of correlation coefficients was accomplished by means of the following transformation. When the proportion was smaller than .50, the estimate was found by taking the square root of 2p. When the proportion was larger than .50, the estimate was found by taking the square root of 2(1 − p). This transformation was based upon the following reasoning.

In the method of paired comparisons, the experimenter instructs his subjects to compare two stimuli, A and B, with respect to a specified attribute. He records the proportion of times that A is judged "greater than" B. When the two stimuli are equal or identical, or nearly so, the proportion approaches a value of .50. The assumption was made that the relationship between the two stimuli could be

represented by a coefficient of determination of 1.00. The coefficient of determination is interpreted as the proportion of variability in one variable accounted for by variability in another variable.

When the two stimuli are quite dissimilar, the proportion approaches a value of zero or 1.00 depending upon which stimulus is judged as having more of the specified attribute. The assumption was made that the relationship indicated by a p value of zero or 1.00 could be represented by a coefficient of determination of zero. Intermediate values were assumed to be given by a linear function.

The estimate of the coefficient of determination was in each instance converted to an estimate of a correlation coefficient by means of a square-root transformation. The matrix of estimated correlation coefficients was factor analyzed by the centroid method (14). Five factors were determined for Saffir's data. The arbitrary orthogonal axes were rotated to simple structure. The new oblique reference axes were then interpreted.

Purpose and hypotheses. That a proportion derived from psychophysical judgments can be used to estimate a coefficient of determination was the basic principle upon which the present study was based. A set of experimental conditions making use of a method of elimination was devised in order to permit the desired interpretation. The stimuli, a selected group of English words, were presented in groups of three to the subjects. The subjects were instructed to underline one word in each triad or group of three which, according to their judgment, did not "belong." The responses were recorded and summarized to indicate the proportion of times the members of each

pair of stimuli were "associated," i.e. the proportion of times the third stimulus word in the triad was underlined and thus eliminated in all of the appearances of the pair. The p values were thus proportional to the similarity or characteristic of "belonging together" of two words. The proportion was assumed to give a crude estimate of the variability in one stimulus word accounted for by the variability in the other. A square-root transformation applied to the estimates of the coefficient of determination yielded estimates of correlation. The resulting matrix of estimated correlations was then factor analyzed.

The major hypothesis of the study was that a psychologically meaningful structure would be revealed if the matrix of estimates of correlation was factor analyzed and the arbitrary orthogonal axes were rotated to simple structure.

The English words, which were used as stimuli in the psychophysical experiment, were chosen on the basis of information concerning their factorial composition which was obtained in a previous factor analysis of the correlations obtained from affectivity ratings on the stimuli. A minor hypothesis of the study was that the factorial structure determined by factoring estimates of correlation from psychophysical data would be similar to the structure found by factoring the correlation data on affectivity ratings.

The psychophysical methods occupy an important position in psychological measurement. When complex stimulus configurations are used, however, efforts at measurements have been considerably hampered by our lack of knowledge of the basic dimensions on which

judgments are made by the respondents. A valid and efficient method
for determining the dimensions of a given psychophysical domain would
be of great value in the identification of the fundamental character-
istics of stimulus objects in perception. The dynamics of visual
perception have not been studied sufficiently from the standpoint of
rigorous psychophysical methods (3). It is to be argued that phe-
nomenological studies of visual perception, such as have most com-
monly been made in the past (7) do not permit adequate quantifica-
tion and prediction for completely scientific analyses of human
visual perception. The methods tested in the present study have
been directed, according to Andrews (1), toward a psychophysical
scheme for studying perceptual variables.

CHAPTER II

PROCEDURE OF THE INVESTIGATION

An attempt has been made in the present investigation to test further the possible use of multiple-factor analysis in determining the basic dimensions of data obtained from psychophysical judgments. The two hypotheses which guided the planning of the research have been stated in the first chapter.

The research involved the following three major steps:

1. A matrix of intercorrelations among English words which was available from a previous study was factor analyzed and stimulus words were selected on the basis of their factorial composition for further experimentation.

2. A psychophysical experiment was performed in which judgments of the selected stimulus words were obtained using a method of elimination. A matrix of proportions was obtained.

3. Estimates of correlation were derived from the proportions obtained in the psychophysical experiment and the matrix of estimates of correlation was factor analyzed. The factorial structure was rotated and interpreted.

The selection of the stimulus words. A matrix of intercorrelations of affective reactions to thirty-two English words was available to the investigator from a previous study by Guilford and Andrews (4). The intercorrelations were tetrachoric coefficients

based upon ratings of the affectivity of each one of the thirty-two words. Four hundred students at the University of Nebraska served as subjects in the study which was conducted at the University in 1939. The subjects were instructed to judge each word as to its pleasantness and record the judgment on a five-point graphic rating scale. Tetrachoric correlation coefficients were computed from the ratings on all possible pairs of thirty-two words chosen from a larger group.

The thirty-two English words chosen are listed below and are numbered as they occur in the correlation matrix in Table 1.

1.	mastery	17.	inconveniences
2.	beauty	18.	food
3.	insult	19.	divorce
4.	sweet	20.	swamp
5.	begging	21.	fondness
6.	disgust	22.	lightning
7.	approval	23.	enterprise
8.	choking	24.	bells
9.	to possess	25.	social-climbers
10.	style	26.	warmth
11.	suspicion	27.	cheating
12.	aroma	28.	butcher
13.	cribbing	29.	love
14.	rotting	30.	accidents
15.	friends	31.	to explore
16.	electric shocks	32.	symphony

The matrix of tetrachoric correlation coefficients was factor analyzed. Nine factors were determined. The resulting arbitrary orthogonal reference axes were rotated to simple structure by the use of two-dimensional sections (14). After eight rotations the configuration was judged to be stable enough to permit inspection of the loadings and interpretation of the oblique reference axes.

On the basis of the interpretation of the oblique factorial structure of the thirty-two English words, fifteen of the words,

TABLE 1. Intercorrelations of

Word	1	2	3	4	5	6	7	8
1	–							
2	.260	–						
3	-.075	-.276	–					
4	-.037	.435	-.402	–				
5	-.095	-.121	.208	.020	–			
6	-.115	-.019	.163	-.288	.112	–		
7	.231	.126	-.196	.200	-.027	-.250	–	
8	-.010	-.061	.367	-.100	.142	.162	-.112	–
9	-.253	.212	-.211	.420	-.092	-.212	.525	-.105
10	-.028	.259	-.097	.275	-.030	-.025	.188	-.188
11	-.089	.028	.133	.185	-.060	.310	-.125	-.105
12	.066	.008	.082	-.025	-.025	-.005	.112	.190
13	-.056	.018	-.090	.000	-.075	-.100	-.275	.038
14	-.008	-.068	.282	-.280	.275	.428	.062	.200
15	.034	.312	-.172	.191	-.275	-.170	.088	-.125
16	-.110	-.085	.267	-.260	-.100	.212	-.125	.288
17	.066	-.144	.252	-.325	-.030	.138	-.275	.212
18	-.023	.139	-.051	.238	-.212	-.100	.115	-.112
19	-.095	.103	.310	-.152	.102	-.625	-.188	.055
20	-.007	-.119	.322	-.230	-.012	-.512	-.062	.300
21	-.066	.320	-.155	.481	.066	-.300	.250	-.150
22	-.028	-.082	.314	-.225	.010	-.080	.112	.225
23	.052	-.056	.052	-.012	-.100	-.025	.412	-.088
24	-.077	.118	-.012	.062	.052	-.162	.150	.000
25	.017	.065	-.046	.112	.100	-.005	-.068	.000
26	-.027	.200	-.046	-.142	-.225	-.212	-.150	-.038
27	-.075	-.289	.170	-.130	.180	.070	.000	.115
28	.097	-.010	.088	-.025	.010	.125	-.080	.068
29	-.006	.250	-.200	.328	-.100	-.150	.050	-.138
30	-.020	-.264	.271	-.275	.112	.138	.062	.325
31	.108	.112	.090	-.075	-.125	-.088	-.100	.050
32	-.030	.127	-.042	.028	-.012	-.005	.212	-.068

Affective Reactions to English Words

9	10	11	12	13	14	15	16	Word
								1
								2
								3
								4
								5
								6
								7
								8
–								9
.355	–							10
-.075	.038	–						11
.090	.080	-.150	–					12
-.080	.062	-.175	.088	–				13
-.012	.060	-.040	-.075	.130	–			14
.050	.180	-.010	-.075	-.125	-.238	–		15
-.100	-.238	.100	.038	.025	.075	-.170	–	16
-.270	-.150	.055	.100	.150	.200	-.050	.212	17
-.112	.042	.125	.038	.025	-.100	.318	-.115	18
-.038	-.100	.140	-.100	.188	.138	-.175	.100	19
-.068	-.202	.190	-.068	.075	.388	-.152	.288	20
.275	.275	-.175	.125	.100	.050	.075	-.250	21
-.062	-.175	-.005	.055	-.040	.168	-.150	.475	22
.260	.325	-.182	.180	-.138	.112	.068	.025	23
.025	.275	-.155	.168	-.175	.068	.150	-.088	24
.060	.100	.100	-.130	.112	.025	.055	-.115	25
.175	-.078	-.038	-.060	.050	-.025	.175	-.075	26
-.142	-.080	.150	-.100	.278	.342	-.325	.075	27
.088	-.075	.068	-.125	.050	.225	.010	.235	28
.070	.168	.075	-.142	.050	-.165	.440	.012	29
-.165	-.050	.000	.175	.038	.288	-.368	.212	30
-.100	-.030	.125	-.012	-.050	-.038	.225	.075	31
.115	.100	-.050	.038	-.190	.000	.155	-.038	32

TABLE 1. Intercorrelations of

Word	17	18	19	20	21	22	23	.24
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17	–							
18	-.150	–						
19	.125	.045	–					
20	.430	-.100	.382	–				
21	-.138	.000	.000	-.238	–			
22	.230	-.212	.238	.388	.050	–		
23	.012	.168	-.038	-.088	.255	.175	–	
24	-.125	-.040	-.188	-.168	.138	-.112	.200	–
25	.112	.070	.100	.000	.255	-.012	.040	.015
26	.050	.238	.050	.100	.050	.030	-.068	.075
27	.075	-.205	.168	.150	-.150	.175	-.138	.000
28	.138	-.050	.225	.380	.075	.338	-.070	-.175
29	-.225	.390	-.070	-.068	.438	-.112	-.015	.138
30	.138	-.370	.188	.225	-.062	.375	.055	-.100
31	.125	.112	.050	.320	.038	.168	.068	.138
32	-.125	.012	-.088	-.050	.150	.125	.168	.275

Affective Reactions to English Words (Cont.)

25	26	27	28	29	30	31	32	Word
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10
								11
								12
								13
								14
								15
								16
								17
								18
								19
								20
								21
								22
								23
								24
-								25
-.025	-							26
-.168	-.300	-						27
.125	.400	.088	-					28
.000	-.300	-.475	-.012	-				29
-.100	-.150	.375	.088	-.500	-			30
-.075	.500	-.175	.090	.100	-.242	-		31
-.075	-.125	-.025	.025	.050	-.043	.342	-	32

representing four of the factors, were selected for use in the psycho-physical experiment. Five new words not in the original list of thirty-two were added to the group of fifteen. The five additional words were chosen on the basis of an a priori judgment as to their factorial composition. Each of the five new words was judged to be related to one of the four factors involved in the composition of the fifteen words which were selected initially.

The twenty words which were finally chosen to be used in the psychophysical experiment are listed below. The words are numbered as they appear in subsequent tables. The five new words which were added on the basis of a priori judgments are indicated by means of asterisks. The words are grouped according to their hypothesized factorial composition. The nature of the factors and other results of the factor analysis of the tetrachoric correlation matrix will be discussed in the third chapter.

1.	friends	12.	enterprise
2.	love	13.	approval
3.	food	14.	bells
4.	health*	15.	fondness
5.	mother*	16.	aroma
6.	swamp	17.	electric shocks
7.	divorce	18.	accidents
8.	lightning	19.	choking
9.	insult	20.	drowning*
10.	argument*		
11.	crime*		

The psychophysical experiment. The twenty words which had been selected for the experiment were grouped in all possible combinations of three words yielding 1,140 triads. The triads were typewritten on forms which were then mimeographed for use as stimulus materials

in the experiment. Sample copies are presented in Appendix A.

The following principles were observed in arranging the words on the stimulus sheets:

1. Each word appeared equally often in each of the three possible positions.

2. No word was allowed to appear in two immediately successive triads.

3. An attempt was made to have each word followed by every other word an equal number of times. The condition could only be approximated because of the complex interlocking nature of the triads.

4. Each one of the twenty words appeared 171 times in the complete arrangement of words. An attempt was made to space the repeated appearances of each word throughout the length of the entire list. The condition also could only be approximated.

5. The triads were numbered ordinally in the order in which they were to be judged by the subjects in the experiment.

The whole task involved in the psychophysical experiment would have required the judgment of each triad or a total of 1,140 judgments from each subject. Because the task was judged to be too demanding to be performed by a single individual, it was divided into four equal and overlapping parts, each part consisting of 285 triads.

Four groups of subjects were used. Each group consisted of thirty male college students obtained from psychology classes at The Pennsylvania State College. Each one of the four parts of the task was assigned to one of the four groups of subjects.

The 285 triads assigned to a particular group of subjects were selected according to the following principle. Each pair of words occurred eighteen times in the 1,140 triads. An attempt was made to have each group of subjects contribute an equal number of judgments to each pair of words. The condition could only be approximated because the eighteen occurrences could not be equally divided among the four groups and because of the complex interlocking nature of the triads. In general each group contributed from four to six judgments to the eighteen judgments which were possible for each pair of words.

The subjects were met by the experimenter in small groups. The mimeographed stimulus sheets with an attached sheet of instructions were distributed to the subjects. The instructions were carefully reviewed with the subjects by the experimenter (See appendix B).

The subjects were given the following instructions:

A number of English words are presented in groups of three on the following pages. Examine each group of three words carefully and then underline the word which you think does not belong with the other two. Here is a simple example:

dog

cat

paint

In this case you would likely underline the word "paint" because the words "dog" and "cat" both refer to animals.

Many of the triplets which appear on the following pages will not be as easy to judge. In each case make the best choice you can. There are no correct answers but underline one word in every group. Do not spend much time on any one group. Do not compare the words as parts of speech such as whether some are nouns, or verbs, or as to the kinds of letters or the number of letters in each word. Judge the words with respect to any

other characteristics they may seem to possess except artificial
physical characteristics. Remember there is no right or wrong
answer for any of these items. Be certain to underline a word
in each set of three according to your best judgment. Look
over your paper to be certain you have done so before handing
it in.

No time limit was set for the completion of the task. Subjects
who worked rapidly finished in thirty minutes. Those who worked more
slowly required as long as one hour. There were no indications that
the subjects considered the task to be an unreasonable one. A few
subjects reported voluntarily that they had experienced some difficulty
in making the initial judgments. A few reported a disturbing change
of frame of reference from time to time as they carried out the task.

The responses were tallied for each one of the triads. The
frequency with which the members of each possible pair of words
was associated was next determined. The frequency of association
for a pair of words was the number of times the third member of the
triad was underlined on the occasions of the appearance of the pair
of words in question together in triads. Because each pair of words
appeared eighteen times, there were eighteen frequencies to be summed
to yield a single number representing the total frequency of association
between the two members of each possible pair of words.

Because each one of the 1,140 triads was judged by thirty subjects,
it was possible for any pair within a triad to be associated as
many as thirty times. Each pair appeared a total of eighteen times
and on each appearance could have been associated by thirty subjects.
Therefore, the greatest possible number of judgments associating any
given pair was 30 x 18 or 540.

A relative frequency of association (proportion) was computed to four decimal places for each pair of words. The proportion was found by computing the ratio of the observed frequency of association for each pair of words to the greatest possible frequency which was 540.

The conversion of proportions to estimates of correlation. Each of the proportions was assumed to be an estimate of the coefficient of determination for a pair of words. To obtain an estimate of the correlation coefficient, the square root of each proportion was obtained. The estimates of correlation were rounded to two decimal places.

The factor analysis of the estimates of correlation. The 20 x 20 matrix of estimates of correlation was factor analyzed by means of the centroid method. The arbitrary orthogonal axes were rotated to simple structure through the use of two-dimensional sections. Six rotations were required. No further rotations were indicated from an inspection of the plots, and they were accepted as the essential configuration for purposes of interpretation. As a final step, the factorial composition of the twenty words as determined by the psychophysical data was compared with the factorial composition indicated in the original correlation data on the words.

CHAPTER III

RESULTS

The results for each one of the three phases of the research are presented here. The three phases of the research included the factor analysis of the correlation data which were available from an earlier study; the psychophysical experiment; and the factor analysis of the estimates of correlation derived from the psychophysical data.

Factorial composition of the words determined from correlation data. Factor analysis of the matrix of intercorrelations of affective reactions to the thirty-two English words resulted in the determination of nine factors. The centroid matrix F_0 is given in Table 2. The arbitrary orthogonal reference axes were rotated to simple structure. The transform matrix Λ_{09} is shown in Table 3. The oblique factor matrix V_9 is presented in Table 4.

Words which had loadings of absolute value greater than .30 on each factor are listed below. Each word is numbered as it was numbered in the correlation matrix in Table 1 and in the matrices in Table 2 and Table 4. The loadings are also listed for the words.

First Factor

15.	friends	.522
29.	love	.470
18.	food	.463
5.	begging	-.403
30.	accidents	-.449
14.	rotting	-.458
27.	cheating	-.571

TABLE 2. Centroid Factor Matrix F_0 for Matrix of Inter-

	I	II	III	IV	V
1	.105	-.049	-.132	-.198	-.144
2	.448	.211	-.165	.182	-.073
3	-.496	.253	.158	-.157	.267
4	.518	.062	-.054	.445	-.124
5	-.223	-.081	.217	.255	.063
6	-.313	-.288	.268	.158	.649
7	.413	.105	.450	-.087	-.294
8	-.362	.226	.131	-.153	.032
9	.403	.262	.272	.292	-.275
10	.389	.177	.215	.286	.102
11	-.137	.045	-.235	.183	.221
12	.054	.115	.283	-.216	-.089
13	-.129	.043	-.164	.242	-.175
14	-.395	.234	.275	.207	.110
15	.511	.138	-.252	-.143	.263
16	-.433	.295	.039	-.154	.089
17	-.406	.218	-.139	-.177	.101
18	.349	.136	-.303	-.051	.220
19	-.308	.461	-.311	.191	-.236
20	-.447	.623	-.312	-.221	-.112
21	.458	.335	.143	.384	-.122
22	-.356	.486	.184	-.194	-.129
23	.275	.278	.442	-.173	.077
24	.325	.080	.313	-.114	.211
25	.042	.135	-.128	.256	.111
26	.130	.263	-.342	-.231	-.161
27	-.538	-.036	.197	.192	-.182
28	-.213	.389	-.180	.108	-.135
29	.431	.159	-.220	.210	.361
30	-.541	.107	.414	-.058	-.295
31	.140	.371	-.224	-.375	.204
32	.235	.151	.250	-.135	.127

correlations of Affective Reactions to English Words

VI	VII	VIII	IX	h^2	
.199	.160	.243	.249	.277	1
.219	-.133	.114	.066	.394	2
-.071	.147	-.134	-.125	.491	3
-.104	-.074	.116	.330	.627	4
.058	.158	-.163	.148	.249	5
.325	-.428	.323	-.133	1.110	6
-.230	.084	.056	.164	.568	7
.110	.041	.155	.158	.286	8
-.212	-.280	-.139	-.160	.634	9
.093	.106	-.089	-.110	.361	10
-.213	-.207	-.072	-.067	.256	11
.105	.140	.179	-.149	.236	12
.246	.240	.109	.044	.267	13
.252	.204	-.109	-.131	.476	14
.046	-.048	.075	.209	.487	15
-.209	-.286	.287	.097	.525	16
.202	.101	.117	-.142	.358	17
-.172	.136	.108	-.183	.376	18
-.205	.247	-.250	.121	.676	19
-.137	.154	-.231	.317	.943	20
.160	.170	.175	.156	.614	21
-.085	-.167	.184	.089	.528	22
-.108	.172	.080	-.313	.530	23
.223	.166	-.309	.332	.551	24
.098	.115	.109	-.124	.164	25
.324	-.344	-.230	-.279	.636	26
.040	.047	-.170	.129	.449	27
.163	-.272	.054	-.087	.370	28
-.302	.080	.292	.271	.690	29
.095	.055	.091	-.123	.607	30
.204	-.205	-.287	.047	.558	31
.075	-.172	-.163	.235	.292	32

TABLE 3. Transform Matrix Λ_{09} for Centroid Matrix F_0

	A	B	C	D	E	F	G	H	I
I	.477	-.225	.289	.180	-.315	.099	.172	-.272	.064
II	.021	.673	.420	.513	.182	.306	.245	.276	-.221
III	-.483	-.190	.752	-.001	.086	-.288	.286	.194	-.038
IV	-.468	-.251	-.200	.824	.197	-.075	.059	-.203	-.221
V	.212	-.034	-.094	.061	.730	-.335	.164	-.235	-.150
VI	-.083	-.145	.276	.081	.532	.708	-.260	-.151	.405
VII	.039	.282	.210	-.031	-.040	-.326	-.707	-.454	-.077
VIII	.516	-.273	.068	.122	.059	-.058	-.473	.698	.186
IX	-.009	.470	.029	.007	.001	-.290	.083	.010	.818

TABLE 4. Factor Matrix V_9

	A	B	C	D	E	F	G	H	I
1	.288	.090	.076	-.135	-.083	.099	-.326	.076	.406
2	.232	-.040	.107	.371	-.006	.340	.069	-.007	.133
3	-.234	.312	.087	-.100	.328	-.149	.024	.053	-.266
4	.103	-.055	.031	.495	-.205	-.058	.147	-.062	.197
5	-.403	.039	.050	.113	.185	-.193	-.008	-.179	.032
6	-.097	-.555	-.085	.043	.783	-.036	.122	.241	.018
7	.010	.043	.510	.025	-.426	-.193	.160	.128	.095
8	-.082	.273	.170	-.046	.226	.006	-.091	.283	.151
9	-.192	-.116	.267	.404	-.309	.108	.489	.081	-.287
10	-.075	-.096	.320	.395	.099	.043	.139	-.222	-.178
11	-.017	.013	-.364	.143	.119	-.080	.198	-.010	-.222
12	.064	-.026	.395	-.090	-.019	.067	-.133	.181	-.028
13	-.087	.057	-.048	.214	.082	.165	-.354	-.061	.099
14	-.458	.127	.240	.226	.431	.057	-.071	-.051	-.190
15	.522	.110	.034	.077	.037	.071	.088	-.113	.211
16	.025	.241	-.045	-.020	.145	-.081	.144	.580	-.004
17	.031	.206	-.024	-.074	.305	.190	-.242	.160	-.065
18	.463	.024	-.097	.098	-.051	-.026	-.078	-.120	-.228
19	-.230	.623	-.163	.270	-.114	.019	-.050	-.087	-.166
20	-.074	.913	-.059	.009	.010	.065	.017	.097	.060
21	.033	.054	.412	.593	.004	.121	-.028	-.031	.096
22	-.090	.382	.247	.039	.056	.076	.138	.554	.011
23	.081	-.023	.559	.047	-.036	-.074	.087	.095	-.332
24	-.071	.198	.451	-.004	.165	-.071	.192	-.353	.277
25	.042	-.032	-.034	.311	.186	.088	-.132	-.069	-.145
26	.150	.064	-.054	-.035	-.013	.698	.193	.000	-.075
27	-.571	.131	-.031	.014	.094	-.089	-.015	.033	.037
28	-.081	.165	-.053	.270	.146	.414	.108	.277	-.071
29	.470	.101	-.089	.365	.033	-.318	.029	-.028	.048
30	-.449	.059	.280	-.092	.052	.044	-.117	.360	-.067
31	.228	.361	.079	-.093	.179	.366	.294	-.088	.071
32	-.015	.126	.315	.009	.078	.015	.361	-.021	.189

Second Factor

20.	swamp	.913
19.	divorce	.623
22.	lightning	.382
31.	to explore	.361
3.	insult	.312

Third Factor

23.	enterprise	.559
7.	approval	.510
24.	bells	.451
21.	fondness	.412
12.	aroma	.395
10.	style	.320
32.	symphony	.315
11.	suspicion	-.364

Fourth Factor

21.	fondness	.593
4.	sweet	.495
9.	to possess	.404
10.	style	.395
2.	beauty	.371
29.	love	.365
25.	social-climbers	.311

Fifth Factor

6.	disgust	.783
14.	rotting	.431
3.	insult	.328
17.	inconveniences	.305
9.	to possess	-.309
7.	approval	-.426

Sixth Factor

26.	warmth	.698
28.	butcher	.414
31.	to explore	.366
2.	beauty	.340
29.	love	-.318

Seventh Factor

9.	to possess	.489
32.	symphony	.361
1.	mastery	-.326
13.	cribbing	-.354

Eighth Factor

16.	electric shocks	.580
22.	lightning	.554
30.	accidents	.360
8.	choking	.283
24.	bells	-.353

Ninth Factor

1.	mastery	.406
23.	enterprise	-.332

The words were examined and their loadings on each factor were interpreted.

The first factor in the oblique factor matrix V_9 was bipolar. The words and their referents are of such a nature that there would be, in our society, almost universal agreement on their assignment to opposite poles of a gradient of desirableness-undesirableness.

The words listed for the second factor suggest a gradient of unpleasantness, characteristic of objects and events in everyday life.

The words listed for the third factor suggest a dimension of approval, appropriate to a varied group of symbols which usually evoke positive reactions in our society.

The words listed for the fourth factor appear to lie on a scale of romantic associations.

The fifth factor appears to be bipolar. One pole has to do with negative affectivity but no further attempt has been made to identify the dimension.

No attempt was made to interpret the sixth or seventh factors.

The list of words for the eighth factor includes one with a loading of .283. The word was included because it appeared to belong

in a group of words which indicate a characteristic of dangerousness connected with certain experiences and events of life.

No attempt was made to interpret the ninth factor.

Inspection of Table 5 which includes the cosine matrix C_9 for factor matrix V_9 reveals considerable variability in the cosines. When the cosines are negative, we may infer that the angles separating the reference vectors are obtuse. Consequently the primary factors will be separated by acute angles. The appropriate interpretation is that the primary factors are positively correlated. When the cosines are positive, we may infer that the angles separating the reference vectors are acute. Consequently the primary factors will be separated by obtuse angles. The appropriate interpretation is that the primary factors are negatively correlated.

Fifteen of the thirty-two words were selected on the basis of their factorial composition to be used in the psychophysical experiment. The three words which were selected from the positive pole of the first factor were friends, love, and food. The four words which were selected from those having high loadings on the second factor included swamp, divorce, lightning, and insult. The five words which were selected from those having high loadings on the third factor were enterprise, approval, bells, fondness, and aroma. The words chosen from those with high loadings on the eighth factor included electric shocks, accidents, and choking.

Five new words were added to the experimental stimuli on the basis of an a priori judgment as to their factorial composition with reference to the factors determined in the previous analysis. Two words, health and mother, were added to the group chosen to represent

TABLE 5. Cosine Matrix C_9 for Factor Matrix V_9

	A	B	C	D	E	F	G	H	I
A	1.000								
B	-.013	1.000							
C	-.123	.142	1.000						
D	-.221	.046	.121	1.001					
D	-.141	-.001	.085	.295	1.000				
F	.058	-.046	.102	.151	.126	.999			
G	-.295	.058	.090	.159	.008	.000	1.000		
H	.182	-.023	.157	-.002	-.080	.093	.057	1.000	
I	.168	.158	.087	-.229	.014	.080	-.163	.106	.999

the first factor. Two words, crime and argument, were added to the group representing the second factor. One word, drowning, was added to the group representing the eighth factor.

The complete list of the twenty words which were used in the experiment is given below. The words are renumbered as they appear in subsequent tables. They have also been grouped according to their factorial composition. The five new words added on the basis of _a priori_ judgments are indicated by asterisks.

1.	friends	12.	enterprise
2.	love	13.	approval
3.	food	14.	bells
4.	health*	15.	fondness
5.	mother*	16.	aroma
6.	swamp	17.	electric shocks
7.	divorce	18.	accidents
8.	lightning	19.	choking
9.	insult	20.	drowning*
10.	argument*		
11.	crime*		

The results of the psychophysical experiment. The psychophysical experiment which made use of a method of elimination yielded a matrix of proportions. Each proportion represented the relative frequency with which a particular pair of words had been associated by the respondents. The matrix of proportions computed to four decimal places is shown in Table 6.

Each proportion was assumed to be an estimate of a coefficient of determination for a given pair of words. The proportion was converted to an estimate of correlation by means of a square-root transformation. The estimates of correlation which resulted from

TABLE 6. Relative Frequency of

Word	1	2	3	4	5	6	7	8	9	10
1	-									
2	.7556	-								
3	.5815	.5352	-							
4	.5870	.6352	.7741	-						
5	.8685	.8537	.6352	.5722	-					
6	.0519	.0315	.1667	.1352	.0741	-				
7	.1556	.3278	.0481	.1074	.1926	.3111	-			
8	.0519	.0519	.0611	.1259	.0407	.6111	.3407	-		
9	.1537	.1833	.0333	.0722	.0815	.3370	.7981	.3611	-	
10	.1944	.2259	.0407	.0907	.1426	.3259	.8852	.3481	.9093	-
11	.0630	.0963	.0315	.0611	.0222	.4833	.7389	.4519	.6852	.6593
12	.5389	.4667	.4130	.4963	.4167	.0981	.2241	.1444	.1370	.2389
13	.7574	.8000	.4963	.5815	.7019	.0389	.1630	.0389	.2481	.2667
14	.4667	.5000	.4944	.3278	.4574	.1704	.0926	.3370	.0667	.0833
15	.8204	.9389	.5870	.5963	.8296	.0278	.2074	.0481	.1833	.1963
16	.3815	.4833	.8722	.4593	.4611	.3019	.0519	.1870	.1204	.0667
17	.0259	.0407	.0704	.2000	.0204	.4815	.4148	.9111	.4370	.4444
18	.0593	.0333	.0389	.2741	.0463	.6037	.5519	.7333	.4648	.5093
19	.0315	.0370	.3259	.2574	.0407	.5185	.4093	.5667	.5296	.5407
20	.0407	.0278	.0667	.2481	.0278	.7741	.5222	.6611	.4093	.4519

Association for Each Pair of Words

11	12	13	14	15	16	17	18	19	20	Word
										1
										2
										3
										4
										5
										6
										7
										8
										9
										10
-										11
.2852	-									12
.0852	.5074	-								13
.1056	.3667	.3796	-							14
.0611	.4278	.8204	.4167	-						15
.0667	.3130	.4759	.3870	.5352	-					16
.5648	.1111	.0407	.4037	.0463	.1574	-				17
.6648	.1630	.0259	.1500	.0259	.0519	.7500	-			18
.7074	.1037	.0370	.0685	.0500	.2333	.6352	.7407	-		19
.6463	.0593	.0259	.0926	.0259	.0667	.6537	.8574	.8944	-	20

the conversion or transformation are given in the matrix in Table 7.
The estimates of correlation were rounded to two places. Only positive
values of the roots were used.

The factorial composition of the words based on psychophysical
data. The matrix of estimates of correlation was factor analyzed.
Six factors were determined. The centroid matrix $F_0^!$ is presented in
Table 8. The arbitrary orthogonal axes were rotated to simple
structure. The transform matrix is given in Table 9. Six rotations
were required and the resulting oblique factor matrix $V_7^!$ is given in
Table 10. Since no further rotations were indicated from an inspec-
tion of the plots, they were accepted as the configuration for
interpretation.

Words having loadings above .30 on the six factors of the
oblique factor matrix $V_7^!$ are listed below. The words are numbered
as they appeared in the matrix of proportions in Table 6 and the
matrix of estimates of correlation in Table 7. Factor loadings are
also listed for the words in each group.

<div align="center">

First Factor

</div>

3.	food	.93
5.	mother	.88
15.	fondness	.87
1.	friends	.84
2.	love	.84
4.	health	.82
13.	approval	.80
16.	aroma	.75
12.	enterprise	.60
14.	bells	.60

Frequency of Association by Square-Root Transformation

11	12	13	14	15	16	17	18	19	20	Word
										1
										2
										3
										4
										5
										6
										7
										8
										9
										10
-										11
.53	-									12
.29	.71	-								13
.32	.61	.62	-							14
.25	.65	.91	.65	-						15
.26	.56	.69	.62	.73	-					16
.74	.33	.20	.64	.22	.40	-				17
.82	.40	.16	.39	.16	.23	.87	-			18
.84	.32	.19	.26	.22	.48	.80	.86	-		19
.80	.24	.16	.30	.16	.26	.81	.93	.95	-	20

TABLE 8. Centroid Factor Matrix F_0' for
Estimated Intercorrelations

	I	II	III	IV	V	VI	h^2
1	.73	-.57	.18	.10	-.06	-.14	.92
2	.76	-.56	.26	.09	-.06	.09	.98
3	.72	-.54	-.39	-.28	-.19	.12	1.09
4	.78	-.40	-.24	.13	-.31	.17	.97
5	.72	-.59	.11	.04	-.18	-.23	.97
6	.70	.42	-.30	-.09	.08	-.25	.83
7	.77	.38	.43	.09	-.15	.06	.96
8	.72	.46	-.30	.16	.24	-.10	.91
9	.75	.41	.39	-.24	.10	.05	.95
10	.78	.39	.45	-.12	-.04	.05	.98
11	.73	.54	.21	.06	.14	.20	.93
12	.71	-.31	.11	.19	.13	.17	.69
13	.73	-.54	.26	-.10	.10	.03	.91
14	.70	-.30	-.22	.28	.30	-.07	.80
15	.75	-.58	.21	-.05	-.06	.04	.95
16	.72	-.39	-.30	-.36	.21	.03	.94
17	.73	.49	-.31	.20	.22	.19	.99
18	.74	.57	-.16	.28	-.12	-.03	.99
19	.75	.51	-.27	-.26	-.24	.24	1.08
20	.72	.59	-.23	.07	-.23	-.09	.99

TABLE 9. Transform Matrix Λ_{07} for Centroid
Matrix F_0'

	A	B	C	D	E	F
I	.552	.519	.362	.200	-.009	-.036
II	-.809	.688	-.074	.131	-.089	.077
III	-.135	-.107	.923	-.343	.001	-.091
IV	-.072	-.361	-.037	.675	-.646	.051
V	-.131	-.326	.099	.607	.758	-.088
VI	.000	-.098	.000	.000	.007	.987

TABLE 10. Factor Matrix V_7'

	A	B	C	D	E	F
1	.84	-.04	.46	.04	-.07	-.21
2	.84	-.04	.55	.01	-.06	.00
3	.93	.20	-.07	-.10	.08	.09
4	.82	.19	.05	.09	-.29	.16
5	.88	.02	.39	-.05	-.12	-.29
6	.08	.72	-.04	.29	.07	-.22
7	.07	.63	.63	.03	-.21	.04
8	.02	.60	-.03	.56	.03	-.07
9	.03	.68	.62	-.03	.19	.00
10	.07	.68	.67	-.05	.01	.01
11	-.08	.64	.43	.27	.01	.18
12	.60	.02	.39	.27	.00	.11
13	.80	-.02	.56	-.02	.18	-.08
14	.60	-.01	.09	.55	.07	-.11
15	.87	.00	.50	-.07	.03	-.05
16	.75	.20	.05	.08	.42	-.04
17	.01	.59	-.04	.59	-.01	.22
18	-.04	.74	.06	.39	-.33	.03
19	.09	.92	-.03	-.01	-.06	.28
20	-.02	.86	-.02	.21	-.28	-.02

Second Factor

19.	choking	.92
20.	drowning	.86
18.	accidents	.74
6.	swamp	.72
9.	insult	.68
10.	argument	.68
11.	crime	.64
7.	divorce	.63
8.	lightning	.60
17.	electric shocks	.59

Third Factor

10.	argument	.67
7.	divorce	.63
9.	insult	.62
13.	approval	.56
2.	love	.55
15.	fondness	.50
1.	friends	.46
11.	crime	.43
5.	mother	.39
12.	enterprise	.39

Fourth Factor

17.	electric shocks	.59
8.	lightning	.56
14.	bells	.55
18.	accidents	.39

Fifth Factor

16.	aroma	.42
18.	accidents	-.33

Sixth Factor

None

After an examination of the words having high loadings on each of the factors, an interpretation was made of them.

The first factor was interpreted as a dimension of positive affectivity. All of the words used in the experiment which possess a positive value in our culture have high loadings on the first factor.

The second factor appears to indicate a dimension of negative affectivity or unpleasantness. All of the words refer to events or objects which are considered unpleasant and are usually avoided by most people in our culture.

The third factor strongly suggests a social dimension. All of the six words with the highest loadings on the factor, including argument, divorce, insult, approval, love, and fondness, refer to interpersonal relationships and influences.

The fourth factor is much more difficult to interpret. The three words with the highest loadings, electric shocks, lightning, and bells, are stimuli and there may be a dimension having to do with the stimulus quality of the referents for human beings. The fourth word does not fit so well the interpretation, although "accidents" can be conceived of as having stimulus qualities. The fact that only four words have appreciable loadings on the fourth factor also adds to the uncertainty of interpretation.

No interpretation was attempted for the fifth and sixth factors. It is possible that they represent error variance.

Inspection of Table 11 which presents the cosine matrix C_7' for factor matrix V_7' reveals that most of the cosines of any magnitude are negative. We may infer that the angles separating the reference vectors are obtuse in the case of negative cosines. The primary factors will then be separated by acute angles. The appropriate interpretation is that the primary factors are positively correlated. An opposite interpretation is to be made in the case of the few positive cosines.

TABLE 11. Cosine Matrix C_7' for Factor
Matrix V_7'

	A	B	C	D	E	F
A	1.000					
B	-.187	1.000				
C	.125	.019	1.000			
D	-.077	-.211	-.219	.999		
E	.014	-.081	.103	.010	1.000	
F	-.062	-.042	-.113	.015	-.099	1.000

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The final discussion of the results of the investigation will

be concerned especially with the consequences for the hypotheses which

guided the planning of the research. There were two such hypotheses.

Whether or not they were confirmed by the results of the research will

be considered below. Attention will be given first, however, to the

results of the original correlation study and the results of the psycho-

physical experiment. The evaluation of the hypotheses will be fol-

lowed by consideration of the implications of the study for theory

and experimentation, and suggestions for further research.

The correlation study. The factor analysis of the matrix of

intercorrelations of affective reactions to the thirty-two English

words from the study of Guilford and Andrews (4) resulted in the

determination of certain dimensions or factors. The successful use

of factor methods on correlation data in the present study represents

no new achievement but rather merely another in a long series of

demonstrations of the value of the methodology in connection with

problems of the kind under consideration.

Affectivity as expressed in the responses of the subjects to the

words was found not to be a single, unitary dimension. The result

is one which is frequently encountered. In many experiments, the

investigator very carefully specifies the attribute concerning which

he wants his subjects to make their judgments only to find evidence
that more than one attribute has been used when the data are examined.
Experience has repeatedly shown the very great difficulty in attempt-
ing to identify a unidimensional attribute of complex stimuli when
there has been no systematic attempt to establish the dimensionality
of the stimuli.

Notice should be taken of the occurrence of a bipolar factor
in the oblique factor matrix V_9. Bipolar factors are not usually
encountered in matrices of intercorrelations among tests of ability.
When we deal with a domain such as affective response to verbal
stimuli, however, it is to be expected that one or more bipolar factors
may be necessary for an adequate determination of the configuration.

The purpose of the study was not primarily concerned with the
problems of human behavior in response to verbal stimuli. Neverthe-
less, a comment would be appropriate here pointing to the adequacy
of correlation and factor methods combined for the possible deter-
mination of the dimensions of meaning, affectivity and other character-
istics of responses to words.

The psychophysical experiment. The method of elimination devised
for the present study proved to be a very satisfactory means of obtain-
ing judgments of the stimuli. Subjects were able to use the method
readily and without apparent difficulty. Long periods of preliminary
instruction in the use of the method were not necessary. The method
may be used with a group whenever the stimuli can be presented to
each member for his judgments without influence from other subjects.

In the present study, the verbal stimuli were presented on typewritten and mimeographed sheets. In other kinds of experiments, use can be made of projection equipment and slides. In still other experiments in which it seems advisable to present the stimuli to one subject at a time, the method can be adapted readily to the purpose.

Examination of the matrix of proportions derived directly from the psychophysical experiment reveals a highly significant range of variability (See Table 6). Consistency of response is necessary to produce the variability found in the matrix. The probability that a random or chance collection of responses could produce the pattern of response found there is quite small.

One of the principal advantages of the method of elimination is that no limitation is imposed upon the subject's perception and interpretation of the stimuli. When the subject is instructed to choose the one object in the triad which does not belong with the other two, he is free to make the judgment on any basis which seems appropriate to him at the moment. The freedom of perceptual or judgmental response permits the greatest possible variation in the dimensions which may appear in the data. Since the stimuli appear in all of the possible combinations of three, the chances for all of the attributes of the stimuli to become apparent to the observer are maximized.

One disadvantage of the method of elimination should be mentioned. When twenty stimuli are used, 1,140 triads are needed to provide for all of the possible combinations. Doubling the number of stimuli increases the number of combinations more than eightfold. The task of making the number of judgments required is nearly impossible for a

single observer. The only alternative is to fractionate the task and use a different group of subjects for each part. Because of the disadvantage in the very large number of judgments required by the method of elimination, the discovery or development of an alternative but shorter method of obtaining the judgments would represent an important contribution to work in the area.

The hypotheses. The first hypothesis stated that the methods of multiple-factor analysis can be used to determine psychologically meaningful dimensions in psychophysical data, when the data are obtained under the proper set of conditions. The hypothesis is confirmed by the results of the factor analysis of the estimated correlations and the subsequent rotations to simple structure. Three dimensions were overdetermined. They were identified as positive affectivity, negative affectivity, and a social factor. The fourth factor, which was not determined as well as the first three, is tentatively identified as environmental stimulation.

The successful determination of the dimensions described above for the verbal stimuli used in the study indicates that psychophysical methods and the techniques of multiple-factor analysis may be used to advantage in studies of the dimensions of meaning, affectivity, and other characteristics of responses to words.

The second hypothesis stated that the factorial composition of the stimuli as it was determined by the factor analysis of correlation data would be confirmed in a later factor analysis of estimates of correlation derived from the psychophysical experiment. The hypothesis

was not supported by the results of the analysis. Four factors were involved in each instance but they were not the same ones.

The failure to confirm the second hypothesis may be due to important differences between the original correlation study of affectivity and the present psychophysical study. In the original correlation study, the attribute of affectivity was specified for the respondents. In the present study, no single attribute was specified. The respondents were free to make their judgments in the psychophysical experiment on whatever grounds seemed appropriate to them at the moment of response. In the original correlation study, one stimulus word was judged at a time in an absolute fashion. In the present study, the judgment was always a relative one involving a combination of three words. In the latter case, the opportunity for different attributes of the words to be apparent was maximized. A time span of fourteen years and its attendant changes in students' frames of reference separated the two studies. The two studies were conducted at universities geographically distant from one another. In the earlier study the subjects included both men and women. In the later study only men were used.

It is entirely possible that the differences discussed in the preceding paragraph account for the failure of the results to confirm the second hypothesis. The hypothesis should be subjected to further testing in future research before it is abandoned as untenable.

Implications of the present research. The successful use of multiple factor analysis in connection with psychophysical data represents at least one possible solution to the dimensionality

problem in psychophysics. Therefore, the results should be of immediate theoretical interest to psychologists who have been concerned with the problem and who have been working toward its solution. If the validity of the procedure for estimating correlations from proportions receives continued confirmation in further research, then the procedure for determining the dimensionality of psychophysical data is a straightforward one. The methods of multiple-factor analysis are efficient and provide a method for establishing psychologically meaningful reference axes as a basis for interpreting the dimensionality.

In addition to the immediate theoretical problem of the dimensionality of psychophysical systems, there is the problem of establishing adequate scales for the measurement of psychological traits. Because of the almost universal desirability of unidimensional scales, a method which would assist in establishing such scales should be welcomed by psychologists concerned with measurement. The possibilities of establishing scales of a single dimension for complex stimuli are considerably improved when the stimuli can be selected on the basis of knowledge of their factorial composition. Having identified a particular dimension, the psychologist who wishes to work with that scale can select only those stimuli which have high loadings on the factor in question and low complexity. The procedure is a well-established one used in the construction of mental tests.

The results of the present study also have important implications for experimentation in psychology. The choice of experimental variables is often made without adequate consideration of the basic dimensions of the domain in which the work is to be done. The methods outlined

here may very well be applied to complex stimuli in psychophysical experiments for the purpose of determining the basic dimensions and ultimately of selecting the stimulus variable or variables most appropriate for experimentation as judged by their factorial composition.

Two areas of investigation in which the determination of the basic dimensions of complex stimuli is of current interest and importance are the fields of meaning and perception.

Osgood (8) has discussed the measurement of meaning and has suggested factor analysis as the basic methodology. Psychophysical methods of the kind used in the present study would be of considerable value in producing the basic data from which the dimensions of a semantic space could be determined.

In the field of perception, there is a need for methods by which the basic dimensions of complex stimuli can be determined. Establishing the dimensionality of such stimuli would permit the formulation of sets of materials which could be used for the controlling of perception in experimental investigations. The methods of the present study may contribute to the solution of this important problem.

Suggestions for future research. Although positive results were obtained in the present study, the methods of the study certainly need to be applied and tested in further research. An initial step might involve repetition of the present study to stabilize the probability associated with confirmation of the hypotheses examined. No observation ever achieves the status of a fact in science on the basis of one performance of an experiment.

In view of the negative results obtained concerning the second hypothesis, further research should be planned for the testing of that hypothesis. If possible, other bases for hypothesizing a particular structure should be explored. One possibility would be to use the methods of the study on a set of simple stimuli in which the physical dimensions of the stimuli were known to be closely related to psychological attributes of response to the stimuli. Another possibility is to continue the studies of complex stimuli using correlation data obtained under appropriate conditions to provide a basis for hypothesizing a particular factorial structure. The conditions of the correlation study should be, in all possible respects, comparable to the conditions of the psychophysical experiment.

Studies of the kind suggested above would answer the question as to the generality of the proper use of the methods and would establish the conditions under which these methods should be used.

A series of studies might be planned to follow one upon another, for the systematic selection of stimuli which most adequately represented the basic dimensions of a given domain. An initial factor analysis of the psychophysical data gathered on a collection of stimuli would provide hypotheses for the selection of stimuli and the addition of other stimuli. Responses to the revised collection of stimuli could be factor analyzed and the structure examined in terms of the hypothesis. The process could be continued with further selection and factoring. A set of stimuli which represented in equal and adequate fashion all of the basic dimensions of a given domain could be achieved finally.

Attention should be given to the discovery or invention of additional methods of obtaining estimates of correlation from psychophysical data. The investigation by Coombs and Satter (2), in which correlations were computed from the formula based on the number of common elements, should be mentioned here as offering possibilities. When new methods are forthcoming, the factorial structure determined by the use of one method can be compared with the structure resulting from use of other methods of estimating the correlations. Checking the results of using one method of estimation against another, if it leads to confirmation of the hypotheses, will increase our confidence in the methods.

In the present study no opportunity was given for the appearance of bipolar factors. Only the positive roots of the proportions were used as estimates of correlation and the estimates in the resulting matrix were all positive. When the correlations are all positive, rotation to simple structure, if it is possible, will yield positive loadings on all factors except for the influences of error. It is possible that criteria might be developed for the appropriate choice of positive or negative roots in effecting the transformation from proportions to estimates of correlation. The use of negative roots would permit the appearance of bipolar factors and would result in a more adequate determination of the factorial structure.

As research continues on the problems outlined above, there will likely be some attention given eventually to the problem of second-order factors (14). Factors obtained from the estimates of correlation are designated first order factors. Factors obtained from

the correlations of first-order factors are designated second-order factors. The cosines of the angles between the first-order or primary factors may be entered in a correlation matrix and factor analyzed as was the original matrix of estimates of correlation. The existence of one or more second-order factors would be of theoretical interest in domains such as aesthetics, meaning, affectivity and the perception of complex visual and auditory stimuli.

The successful transformation of psychophysical data to estimates of correlation and the subsequent use of the methods of multiple-factor analysis to produce psychologically meaningful dimensions represent important steps in the continuing rapprochement of psychophysics and the mental-test tradition. Factor analysis has been limited in the past to use on correlation data. Extension of its use to psychophysical data reflects a new importance for the method. It is possible that the new approach will further advance the activities and increase the success of psychologists as they work with the problems of dimensionality, as they try to establish well-founded psychological scales, and as they seek meaningful variables for experimental study.

REFERENCES

1. Andrews, T. G. Multidimensional psychophysics: a new research method. (Paper presented at meetings of the Eastern Psychological Association, 1952).

2. Coombs, C. H. & Satter, G. A. A factorial approach to job families. Psychometrika, 1949, 14, 33-42.

3. Gibson, J. J. The Perception of The Visual World. Boston: Houghton-Mifflin Co., 1950. 235pp.

4. Guilford, J. P. & Andrews, T. G. Intercorrelations of affective reactions to English words. (Unpublished).

5. Gulliksen, H. Paired comparison and the logic of measurement. Psychol. Rev., 1946, 53, 199-213.

6. Klingberg, F. L. Studies in measurement of the relations among sovereign states. Psychometrika, 1941, 6, 335-352.

7. Koffka, K. Principles of Gestalt Psychology. New York: Harcourt, Brace & Co., 1935. 720pp.

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

9. Richardson, M. W. Multidimensional psychophysics. Psychol. Bull., 1938, 35, 659-660. (Abstract of paper presented at 1938 meetings of the American Psychological Association).

10. Saffir, M. A. A comparative study of scales constructed by three psychophysical methods. Psychometrika, 1937, 2, 179-199.

11. Spearman, C. The Abilities of Man. New York: The Macmillan Co., 1927. 415pp.

12. Thurstone, L. L. A law of comparative judgment. Psychol. Rev., 1927, 34, 273-286.

13. _____ Primary mental abilities. Psychometric Monogr., 1938, No. 1.

14. _____ Multiple-Factor Analysis. Chicago: The University of Chicago Press, 1947. 535pp.

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

16. Wolfle, D. Factor analysis to 1940. Psychometric Monogr., 1940, No. 3.

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

18. _____ A note on multidimensional psychophysical analysis. Psychometrika, 1941, 6, 331-333.

Appendix A: Sample copies of the stimulus materials used in the psychophysical experiment.

1. fondness
   love
   crime

2. mother
   swamp
   health

3. fondness
   crime
   friends

4. food
   insult
   enterprise

5. health
   lightning
   divorce

6. mother
   bells
   approval

7. love
   food
   health

8. friends
   drowning
   crime

9. love
   food
   mother

10. health
    divorce
    insult

11. approval
    mother
    fondness

12. health
    divorce
    argument

13. love
    food
    swamp

14. friends
    choking
    crime

15. health
    divorce
    enterprise

16. approval
    aroma
    mother

17. choking
    drowning
    crime

18. argument
    food
    enterprise

19. love
    mother
    health

20. approval
    food
    aroma

21. love
    health
    swamp

22. approval
    electric shocks
    mother

23. lightning
    health
    insult

24. friends
    choking
    drowning

1. crime
   mother
   friends

2. argument
   food
   fondness

3. love
   crime
   bells

4. food
   aroma
   accidents

5. health
   electric shocks
   drowning

6. crime
   swamp
   divorce

7. drowning
   lightning
   insult

8. choking
   divorce
   bells

9. approval
   lightning
   crime

10. insult
    drowning
    aroma

11. friends
    crime
    electric shocks

12. enterprise
    love
    accidents

13. insult
    argument
    lightning

14. food
    electric shocks
    choking

15. divorce
    swamp
    insult

16. health
    crime
    approval

17. insult
    argument
    divorce

18. mother
    swamp
    drowning

19. aroma
    approval
    electric shocks

20. drowning
    crime
    enterprise

21. accidents
    choking
    aroma

22. friends
    electric shocks
    drowning

23. argument
    choking
    love

24. food
    accidents
    electric shocks

1. accidents
   friends
   divorce

2. love
   drowning
   bells

3. lightning
   food
   electric shocks

4. choking
   crime
   fondness

5. lightning
   aroma
   health

6. crime
   electric shocks
   bells

7. enterprise
   drowning
   argument

8. lightning
   crime
   accidents

9. approval
   swamp
   choking

10. mother
    drowning
    electric shocks

11. aroma
    friends
    lightning

12. approval
    crime
    love

13. lightning
    food
    aroma

14. divorce
    accidents
    health

15. electric shocks
    bells
    choking

16. approval
    crime
    enterprise

17. divorce
    drowning
    lightning

18. crime
    swamp
    enterprise

19. mother
    choking
    aroma

20. electric shocks
    friends
    divorce

21. love
    approval
    drowning

22. food
    accidents
    divorce

23. approval
    choking
    electric shocks

24. crime
    fondness
    argument

1. swamp
   fondness
   love

2. aroma
   food
   mother

3. drowning
   insult
   health

4. swamp
   enterprise
   mother

5. divorce
   argument
   crime

6. bells
   accidents
   choking

7. electric shocks
   fondness
   aroma

8. approval
   enterprise
   argument

9. swamp
   love
   bells

10. friends
    fondness
    argument

11. health
    mother
    electric shocks

12. swamp
    love
    approval

13. choking
    food
    health

14. health
    insult
    approval

15. choking
    mother
    divorce

16. swamp
    insult
    argument

17. electric shocks
    lightning
    enterprise

18. choking
    insult
    fondness

19. bells
    drowning
    electric shocks

20. aroma
    insult
    argument

21. swamp
    love
    enterprise

22. accidents
    food
    health

23. friends
    argument
    bells

24. love
    choking
    mother

Appendix B: Instruction sheet used in the psychophysical experiment.

ENGLISH WORD STUDY

Name_____ Section_____

A number of English words are presented in groups of three on
the following pages. Examine each group of three words carefully
and then underline the word which you think does not belong with the
other two. Here is a simple example:

dog

cat

paint

In this case you would likely underline the word "paint" because the
words "dog" and "cat" both refer to animals.

Many of the triplets which appear on the following pages will
not be as easy to judge. In each case make the best choice you can.
There are no correct answers but underline one word in every group.
Do not spend much time on any one group. Do not compare the words
as parts of speech such as whether some are nouns, or verbs, or as to
the kinds of letters or the number of letters in each word. Judge
the words with respect to any other characteristics they may seem to
possess except artificial physical characteristics. Remember there
is no right or wrong answer for any one of these items. Be certain to
underline a word in each set of three according to your best judgment.
Look over your paper to be certain you have done so before handing it
in.

Name: William Samuel Ray

Permanent address: Apartment 15, 529 West Foster Avenue,
                    State College, Pennsylvania

Degree to be conferred: Doctor of Philosophy, June 1953

Date of birth: March 16, 1917

Place of birth: Frederick, Maryland

Secondary Education: Frederick High School, Frederick, Maryland

Collegiate Institutions attended	Dates	Degree	Date of Degree
Bridgewater College	1946-49	B.A.	August 1949
University of Maryland	1949-53	M.A.	June 1951

Positions held:

    Boy's Work Secretary, Y. M. C. A., Frederick, Maryland

    Director of Residence, Bridgewater College, Bridgewater, Va.

    Graduate Assistant, Dept. of Psychology, University of Maryland

    Asst. Professor, Dept. of Psychology, Pennsylvania State College