DOCUMENT RESUME

ED 029 618 24 HE 000 991

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Prediction of College Performance and Personality Based on Association Rating of All Possible Sets of Terms in a Course of Instruction. Final Report.

Michigan State Univ., Rochester. Oakland Univ.
Spons Agency-Office of Education (DHEW), Washington, D.C. Bureau of Research.
Bureau No-BR-7-E-012
Pub Date Aug 67
Grant-OEG-3-7-070012-1636
Note-34p.
EDRS Price MF-$0.25 HC-$1.80
Descriptors-*Associative Learning, *Cognitive Ability, *Factor Analysis, Higher Education, *Learning Theories, Projective Tests, *Thought Processes

This study tested whether the word association employed by individual students could be used to predict their performance in a particular course. It was designed to explore a new method for describing the various models used in thinking and to determine whether this approach would yield results that were consonant with current cognitive theory. At the beginning and end of an introductory course in Social Psychology, college freshmen and their instructor filled out association matrices for 20 words that were central to the course. Using 1 word as a subject, the students assigned associability scale values to all possible pairs of words on a 7-point scale, indicating to what degree each of the other words would "fit in" with (top of scale) or change (bottom of scale) the subject. At the end of the term the association matrices were analyzed by a new, non-parametric method of factor analysis, the Matrix Optimizing System (Mopsy). Two major hypotheses of the study were confirmed with levels of correlations in the .3 to .4 range: students whose associative matrices yield a larger number of dimensions under the non-parametric factor analysis tend to get higher grades, and those whose cognitive dimensions match those of the instructor also tend to get higher grades. The Mopsy, which is discussed in detail, is suggested as a probably alternative to standard parametric methods of factor analysis. (WM)

HK ED029618

BR 7-E-012
PA 24

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Donald C. Hildum

August 1967

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

Oakland University

Rochester, Michigan

FINAL REPORT
Project No. 7-E-012
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PREDICTION OF COLLEGE PERFORMANCE AND PERSONALITY BASED ON ASSOCIATION RATING OF ALL POSSIBLE SETS OF TERMS IN A COURSE OF INSTRUCTION

August 1967

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

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Introduction

During the last fifteen years there has been a considerable revival of interest in word association. This revival has been built on four recent developments:

(1) The increase in cognitive studies with the realization that some sort of complex mediation process was necessary to account for human behavior, and the recognition of the central position of language in that process.

(2) The remarkable development of linguistics with its emphasis on language structure at all levels, the present plausibility of machine translation, and the consequent focus on semantics as a linguistic bottleneck which has yet to yield its structural secrets.

(3) A gradual maturing of interest in idiographic studies, as nomothetic approaches are mined out, one by one, and a significant residue remains.

(4) The rapidly advancing state of computing hardware which makes feasible complete idiographic analyses and the processing of the massive data typically generated in verbal studies; and software, the variants of factor analysis and multi-dimensional scaling which search for the latent structures that linguistics tells us to expect.

My concern in this project has been with the derivation of associative structures, rather than with the basic mechanism. The references have been chosen with this concern in mind. While they are not exhaustive, they do represent all the major contributing lines of thought.

The first significant chain is found in clinical psychology. Jung's Studies in Word Association (20) introduced the idea that a systematic study of free associations offered a glimpse of a patient's internal life. The emphasis was primarily on the aberrations or blockages in association, which were thought to indicate specific emotional problems. Schafer (43) asked what was the total set of processes lying behind the word association test, pointing up several which had not been emphasized by the earlier clinical interest in "complexes". Laffal (22), using techniques associated with the study of verbal learning, supported the original hypotheses of association testing by showing that disturbing words took slightly longer to learn than neutral words in a paired association task, and that they produced more variety in free associations. Moss (30) was an early user of the semantic differential who tentatively defined successful therapy as the approximation of affective meanings at the conscious level with those of the unconscious, reached experimentally via hypnosis. Brody (8) continued the process of bringing the studies of normal and disturbed language together by pointing out that subjects with high anxiety present essentially exaggerated forms of the normal response to word association tests. That is to say, they show excessive commonality to words which normally elicit it, and excessive variety to words generally eliciting low commonality. Laffal (25) suggested that patterns of response to association tests grow largely out of general patterns of superordinate categories, and offered a semantic classification scheme for application to clinical content analysis. The sequence in all these clinical studies seems to be from a study of the particular, aberrant response to a study of the pattern of all responses, normal and abnormal, on the grounds that both are necessary for the understanding of either.

A number of recent approaches to content analysis show the operation of a similar trend. Straight frequency studies of special content categories have been partially superseded by variants of contingency analysis. Pool (37) gives an idea of the range of this work, including an experimental demonstration by Osgood of the validity of the assumption that co-occurrence is a measure of association in the source. The new approaches to content analysis find application in two papers by Laffal (23, 24) in the clinical field. One is a contingency analysis, using Laffal's broad category list, of "the contextual associates of sun and God" in the autobiography of a psychotic, for the purpose of checking rival psychodynamic hypotheses about him. The other paper examines changes in category profiles of a schizophrenic patient during therapy. It is interesting to note that contingency analysis, before its recent vogue, was applied to the study of a single personality by Baldwin (2), with an eye to identifying a personal structure. Allport (1), editing the same set of letters that Baldwin worked on, comments on the general agreement between subjective analyses and statistical-structural analyses of the case, and at the same time renews his plea for idiographic analysis.

A somewhat different tack has been taken by the students of verbal learning. Their efforts have aimed at finding the principles of association operating across subjects. The various papers by Bousfield et al (5,6,7) focus on the phenomenon of clustering of associated words in the recall of randomly ordered word lists containing mixtures of categories - a further validation, if you like, of the content analyst's assumptions. Jenkins (18) offers a variety of experimental work on the causes and conditions of verbal learning and word association, notably (for our purposes) including a detailed study of two normal college students with widely differing associative habits and apparently with analogously contrasting personalities. Ervin (12), in a broad discussion of paradigmatic vs. syntagmatic association, shows how the factor of expectancy in listening would provide an explanation for paradigmatic associations. In general, the papers cited here seem to be moving, via massive experimentation, toward more and more complex mediating systems for verbal behavior.

An early set of papers should be mentioned in this context. Razran (39,40) and Riess (41,42) demonstrated that classical conditioning with GSR and salivation as UCRs and words as CS would yield stimulus generalization to associates of the conditioned word, that the amount of generalization to certain classes of words matched the established results of free association tests, including the known changes with age, and that the conditioning could take place without awareness. Even these early results offered the possibility of a kind of semantic distance mapping. Notice that the conditioning experiments did not require a stimulus-response theory. On the contrary, conditioning was only a measuring device operating upon an independently established associative system.

Combining the verbal learning theorists' interest in traditional association data with the naive directness of the conditioning experiments are a group of studies I would put under the label "associative similarity". Flavell (13) and Flavell and Stedman (14) discussed the relation of the semantic differential and co-occurrence to direct judgments of similarity of meaning, arguing the underlying complexity of those judgments, but showing that they could not only be made reliably but were remarkably stable from grammar school through college. Deese (9) introduced the concept of associative overlap and indicated that preliminary data from this measure were related to such things as Rorschach response patterns and value profiles - areas of high value showing higher association levels and more patterning. Marshall and Coffer (29) reviewed ten different measures of association, commenting on their particular values and shortcomings. They note that these indices had been shown to predict, variously, "free recall of verbal lists, mediated transfer between verbal lists, perceptual word-recognition memory, and conditioned generalization". My own effort (17) at an associative index strives to use a more "natural" measurement situation and at the same time to recognize the logical directionality of association in complex structures. The article by Johnson (19) is an application of Deese's associative overlap measure to an educational setting. As such, it is of major interest to me, and for that reason I shall postpone its discussion until later. Deese (10) summed up several years of his and others' work on associations, with extensive application of factor analysis to bring out the associative structure. It is important to note that Deese now presumes - and with good reason - to proclaim in his title that these associative structures are not only in the language but in thought as well. This brief comment cannot do justice to his book, but one point in it is worthy of special mention here: I suspect that his comparative study of factorial structures in adjectives vs. nouns, demonstrating the continuous and non-continuous character, respectively, of their semantic spaces, will prove to be of very great importance.

The sequence of semantic differential (SD) research reports begins with Osgood and Luria (33). This blind analysis of the "three faces of Eve", produced as an early byproduct of more theoretically oriented research, represents a significant success in applying relatively simple semantic solutions to complex clinical problems. The SD is basically a questionnaire presentation of a number of bipolar adjective scales upon which the respondent is asked to rate several concepts. It is the nature of such an elegantly simple design, of course, that varieties - including nonverbal - of concepts and scales may be used. To the respondent's answers some form of factor analysis is applied to yield, variously, clustering of scales across subjects, concepts across subjects, or concepts or scales within one subject. This last result, intra-subject structure, is an especially significant one, lacking in Deese's associative overlap method, but meeting the need for idiographic analysis. As in the Osgood and Luria paper mentioned above, this potential was used by Lazowick (26) and Luria (28) to compare characterizations of self and parents in anxious and neurotic groups and their controls. In the study of attitudes, Prothro and Keehn (38) applied the SD to the description of national stereotypes.

The basic text for users is, of course, Osgood, Suci and Tannenbaum (34). Starting with a basic theory of mediation processes in verbal behavior, they described the development and selection process for the SD and showed a variety of applications to clinical, attitude description, and attitude change problems. Any of these could be looked at either from the individual or the group perspective. The 1960 article by Moss (31) reviewed the spate of SD research, noted its clinical, anthropological, and social psychological applications, and pointed out that its validity has been clearly established, although the interval character of its scaling remained questionable. A series of papers (35, 45, 46, 48) demonstrated the cross-cultural constancy of the basic affective meaning structure, but expected variations in adjective scale makeup and in the scoring of particular concepts. At the same time, SD results, according to Osgood (35), showed a disappointing lack of correlation with IQ and sex.

A final, clearly-definable strand of influence in this area comes from linguistics, especially its anthropological phase. The linguist's tendency is to look for complete, airtight analyses as opposed to statistical ones. In semantics this is a questionable ambition, but the study of kinship terms is a special case. Goodenough (15), Lounsbury (27) and Wallace and Atkins (49) discussed particular kinship systems in detail, defining the semantic components necessary to generate the systems and morphemic equipment used to convey them. Goodenough argues that gaps in the componential structure are likely loci of linguistic and/or conceptual change. In another article, Wallace conjectures, on the basis of kinship data, that 64 terms (the equivalent of six binary distinctions) is a functional maximum for folk terminologies, as distinct from expert or professional vocabularies. He supports the conjecture with numerous examples from anthropology and everyday life.

The best summary I know of for the present state of the semantic art in linguistics is Weinreich (52). In this overview Weinreich attempted to present the range of possibilities of semantic components and their verbal vehicles in all languages. The variety is large, but not so large as to defy analysis.

I have saved for last a motley series of references that might have been parcelled out among the other classifications, but which share the characteristic of being especially close to my intentions because of their strong emphasis on associative structure. Ohman (32) reviewed a whole series of European linguistic studies dating from the 1930s which she classes as examples of field theory. The name Jost Trier was particularly associated with the examination of terminologies or of clusters of near synonyms with an eye to describing their network of semantic relations and, in turn, the sociology and cognition they reflected. These studies were exhaustive rather than statistical in conception, and aimed at presenting group usage, but there seems no reason in principle why the same approach could not be applied to individuals. Indeed, much idiographic analysis by clinicians in the line of duty must be very close to this form of analysis. The previously mentioned study by Baldwin may be taken as a partial instance.

Kelly (21) built a whole behavior and personality theory on the cognitive process, which he argued was made up of binary constructs involving judgments of similarity and contrast. The comparison with both the bipolar scales of the SD and the recurrent theme of contrast in linguistics is extremely suggestive. In the Role Construct Repertory Test, Kelly provided a means for locating and factor analyzing the cognitive distinctions which anyone makes among other persons and himself. Kelly argued that understanding these dimensions, most but not all of which are verbally mediated, was tantamount to understanding the person. Granting this, he said, the concept of motivation becomes unnecessary.

Human Information Processing, by Schroder, Driver, and Streufert (44) is closely related to Kelly's work, but shifts from his clinical emphasis to a small-group, problem-solving focus. These authors take personal complexity as their most important variable, showing how this complexity varies as the person interacts with different sectors of the environment under varying conditions. They define complexity as having two components: differentiation, the making of distinctions among stimuli, using one or several dimensions of classification; and integration, the process of combining these dimensional judgments, comparing them, and generating complex relationships among them.

Boulding (4), it seems to me, echoed Kelly's position when he referred to the image. He used this term broadly, covering variously the whole putative cognitive map carried by any one person - or secondarily shared by a group - and the locally organized parts of such a map. His proposal of a science of eiconics and his recognition that it already exists in fragmentary form in various disciplines strike me as an endorsement of Kelly's theoretical position.

I have saved mention of Weinreich's (51) review of The Measurement of Meaning for this point because I believe it raised - without attempting definitive answers - some major questions about what our conceptions should be of the cognitive maps of individuals and speech communities. He raised serious questions about the implied continuous, uniform space described by the SD, proposing a supplementary, tree-structured, Twenty Questions model as necessary to keep lexicographers happy. This contrast is echoed in Deese's (10) findings about the differing factorial structures yielded by adjectives and nouns.

The Johnson article (19) mentioned previously is the only example I know of in which associative structure has been investigated in the context of education. It is a first effort which must be followed up. Johnson obtained from several groups of high school students free associations to a list of eighteen words selected for their central position in classical mechanics. Then, using only those responses which were themselves members of the original stimulus set, he calculated overlap coefficients for the eighteen terms. He found that students who were taking or had recently taken a physics course showed higher overlap among terms, and those who had no intention of taking the course scored lowest. In my opinion the limitation on the responses used for calculating overlap casts doubt on the significance of the stated group differences, making them seem built in to the experimental design. But it is the overlap matrices themselves which are potentially most interesting. Johnson gives us only the one for his group presently taking physics, with some comment on particular associations but no overall analysis. A rudimentary cluster analysis of his data shows three major clusters: a set of terms having to do with size and weight, a second centering on motion, and, appropriately a third set of energy terms located between the other two clusters. If we had them, the results for the other three groups could be so analyzed, and we would then be in a position to ask about some of the immediate and lasting effects of the physics course in question, in terms of the semantic spaces (or cognitive maps or Images) of the students.

The final reference in this integrative sequence is Belth (3). Belth has asserted that the discipline of education is properly defined as the study of the various models used in thinking. As such, it seems to me, it is identical with Boulding's eiconics. Belth has, I believe, put his finger on an essential point. If we are to conduct effectively the process of adding to people's knowledge and influencing their attitudes, we must be able to state where they are, cognitively, where we would like them to be, and therefore the paths connecting those points. It is quite probable that the study, through various approaches, of individual models of sections of the world is the necessary basis for the discipline of education.

The work reported below is an effort on my part to explore a method for describing such individual models in an educational setting, and to determine whether the approach would yield results consonant with current cognitive theory.

More specifically, I hypothesize that word association data for a single individual on a sample of words within a particular subject area can be analyzed in such a way as to yield useful indication of the person's cognitive organization of that area, as to both content and formal properties, such as complexity. Still more specifically, I hypothesize that the larger the number of dimensions extractable from a person's association matrix in a topic area, the more successfully he will deal with that area, and in particular the higher will be his grade in a relevant course. I hypothesize also, with some trepidation, that the agreement of a student's cognitive structure with that of the instructor will also increase the student's grade.

Around the major hypotheses revolve several derivative ones: that specificity of matching to the instructor's dimensions rather than just sharing a cognitive space, will be more significant; that changes in level of organization or in various matchings will be significantly related to performance level.

Method

Subjects were 67 students, 26 men and 41 women, in a college freshman course called "Introduction to Social Psychology" At the beginning and again at the end of the course the students and the instructor (myself) filled out association matrices for twenty terms central to the course. The students were assured that their results would not affect their course grade, since the analysis was not to be performed until after the end of the term. The twenty terms were: attitude, change, communication, conflict, culture, follower, group, individual, influence, interaction, language, leadership, learning, perception, prejudice, public opinion, role, socialization, society, stratification. The terms were listed down the side and across the top of a 20 x 20 grid. The students were asked to imagine that they were engaged in a conversation or reading a book, and that the row-term was the current subject. They were asked, for each of the row-terms, to state by means of a 7-point scale (-3 to +3) to what degree each of the other terms would "fit right in" (+3) or be "a complete change of subject" (-3). The scale was anchored only at the ends. I made it clear that the judgments were to be personal (not "correct" or "incorrect"), and that the matrix was not required to be symmetric - that is, that the A-B transition might be different from the B-A transition.

Of the 67 students, six completed the initial form but dropped the course and could not be included in the final analysis, though their results are included in some of the purely descriptive summaries. Only 39 students returned the 2nd form, and one of those had done only the second form. N, therefore, is 66 for descriptive statements about the independent variables from the first testing, 60 for correlational statements from first testing, 39 for correlational statements from second testing and 38 for comparisons of first and second testing. All findings are given in terms of ordinal scale statistics.

The association matrices were analyzed individually by Mopsy (the Matrix OPtimizing SYstem) , a form of nonparametric factor analysis. (Mopsy is discussed in detail, with sample analyses, in Appendix A. Since I consider Mopsy to be a major result of this project, I hope the reader will give more than usual attention to that appendix.) Mopsy's output is a series of rank orders which may be treated as orthogonal dimensions of a factor space. Output of new dimensions continues until the matrix is exhausted or until a dimension sufficiently violates the presumption of orthogonality. (In other words, more dimensions are added as long as there is more information in the matrix and as long as that information is sufficiently non-redundant.) Mopsy is programmed in the IBM Symbolic Programming System for the 1620 computer, with on-line printer, 40,000 decimal digits of core storage, and disk storage.

The following items of information were recorded for each student whose data was complete (maximum subsets for others): course grade, average association scale values for both matrices, the match between the student's before- and after structures, and between those and the instructor's before- and after structures; for each of these matchings, a specificity ratio; and for all the above measures, where possible, the change from the first to the second testing.

Some of the measures call for explanation. To match two structures, the student's with his own, or with the instructor's, I first correlated all the dimensions of one with all the dimensions of the other. For the specific match, I selected the set of correlations which would yield the highest possible total sum of squares, with the condition that no row or column could be represented more than once, and the set could therefore be only as large as the number of dimensions in the smaller structure. This allowed for the fact that dimensions in the two structures which otherwise corresponded very well might be extracted in a different order. The root mean square of the selected correlations was taken as a measure of the specific matching of structures. Another figure for total matching was obtained by summing the squares of all the cross-correlations, dividing by the smaller number of dimensions and finding the square root. Specificity of matching was defined as the ratio of the sum of squares of specific to that of total matching.

Results

This statement of results will not be exhaustive, but will attempt to give an impression of the lay of the land, plus the most interesting correlational results.

Grades, on a 4-point scale, varied around a median of 2.58, with an interquartile range of 2.32 to 2.895, and a total range of 1.09 to 3.84. Numbers of dimensions in the first testing ranged from 2 to 6, interquartile (IQ) range 4 to 5, and median 4. In the second testing the range was 1 to 6, IQ range 3 to 4, median 4.

Reliability measurement was a problem. The first and second testing, although they were separated by experience that was expected to change the performance, offer our only check. The number of dimensions, first vs. second testing, correlates .33: a clear relation, but poor reliability. The matching statistic ranged from .25 to .70, IQ range .34 to .47, median .435. The fact that the dimensions were matched by selecting the high values among the correlations exaggerates the level of matching. The correct value would be close to the .33 obtained for number of dimensions.

Matchings of student structures to those of the instructor were, oddly enough, almost identical with the self-matching. The various combinations yielded medians ranging from .395 to .42, an IQ range of about .12, and total ranges from .16 to .79.

Specificity measurements for the different matchings were also about the same, with medians ranging from .515 to .595 (that is, the specific matching of dimensions accounting for a little over half the total shared variance), with an IQ range of about .16 and total ranges from .31 to .89.

Changes from first to second testing, for number of dimensions, matchings, and specificity all varied around a zero or near-zero median.

Mean association values ranged from -0.16 to +2.90, IQ range +0.69 to +1.59, median +0.97 for first testing. Second testing yielded a range from +0.42 to +3.00, IQ range +1.15 to +2.41, median +1.81, a clear increase over the first testing. (The +3 average was produced by a single student who turned in her second matrix with a single, large +3 on it. See discussion of this point below.)

The hypothesis that course grade and number of dimensions are positively related was confirmed, for the first testing only, but at relatively low levels of correlation. The relevant figures are as follows, with correction for the correlation that turned up between association values and grades:

	r		p	
	1st	2nd	1st	2nd
Grades vs. number of dimensions	+.30	-.06	.02	.71
Grades vs. mean association values	+.10	+.29	.44	.07
Number of dimensions vs. mean association values	-.35	-.53	.01	.001
Grades vs. number of dimensions (mean association values constant)	+.36	+.12	.01	.46

The hypothesis that matching with the instructor's structure would be positively related to grades was confirmed, but mostly with respect to the instructor's initial structure only. The significant correlations, all with association value held constant, are as follows:

	r	p
Specific match, student 1st: instructor 1st, vs. grade	+.33	.01
Total match, student 1st: instructor 1st, vs. grade	+.34	.01
Specific match, student 1st: instructor 2nd, vs. grade	+.28	.03
Specific match, student 2nd: instructor 1st, vs. grade	+.37	.02
Total match, student 2nd: instructor 1st, vs. grade	+.43	.01

The above correlations suffer a very slight reduction when the number of dimensions is also held constant, but the picture is basically the same.

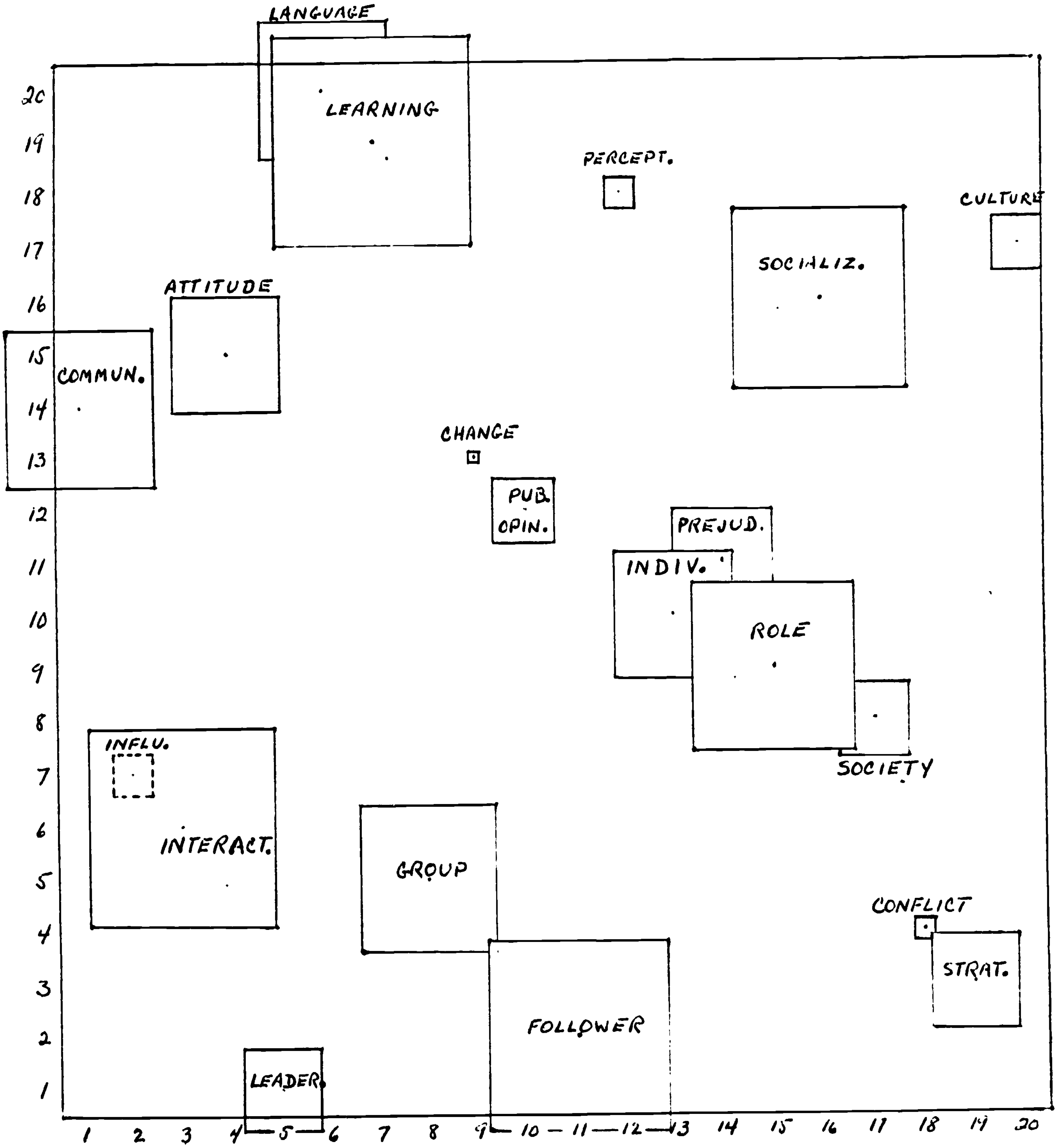
The several measures of specificity showed no relation to course performance. Likewise, no measure of change produced a significant relation to performance.

The next several pages give structural diagrams, together with relevant statistical information, to convey an idea of the Mopsy output and a feeling for the content of this study. Up to three dimensions are presented graphically, with any further orders listed below the diagram. When a term is not included in an order, it is because its matrix row went to zero at an earlier point in the analysis. The first dimension (I) is the vertical, the second (II) horizontal, and the third (III) depth (represented by the block sizes).

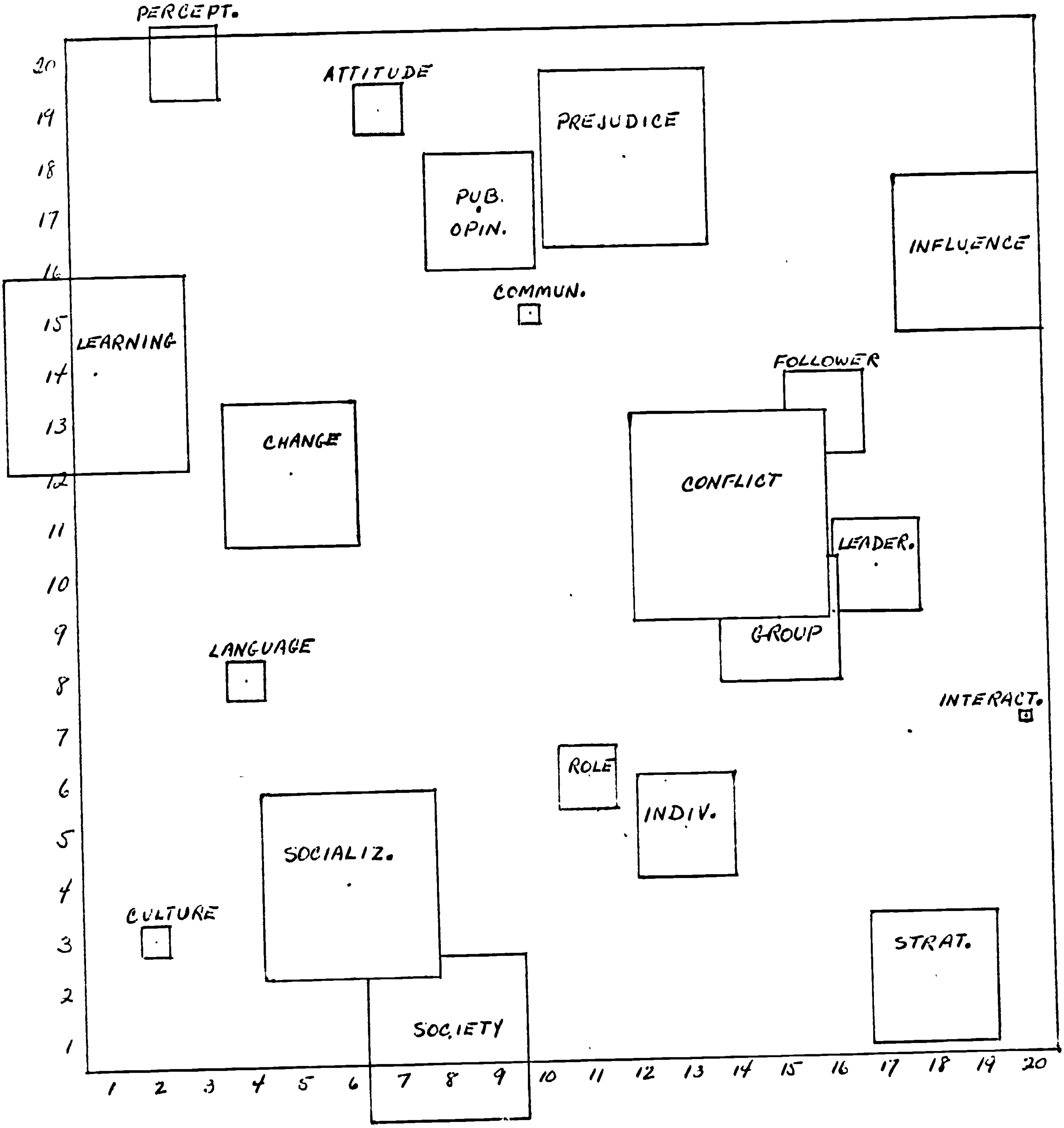
The following correlations are worth noting as you examine the diagrams:

Instructor 1st - I instructor 2nd - II	-.89
Instructor 1st - II instructor 2nd - I	-.52
207 - II ~ instructor 1st - II	-.52
207 - II ~ instructor 2nd - I	+.67
218 - I ~ instructor 1st - II	+.63
218 - II ~ instructor 1st - I	-.77
218 - II ~ instructor 2nd - II	+.64
218 - III ~ instructor 1st - III	-.53
218 - IV ~ instructor 1st - I	+.59
218 - IV ~ instructor 2nd - II	-.61
218 - V ~ instructor 2nd - II	+.52
225 - I ~ instructor 2nd - I	-.71
501 - I ~ 501 - II	+.59

INSTRUCTOR: 1ST TEST



INSTRUCTOR 2ND TEST

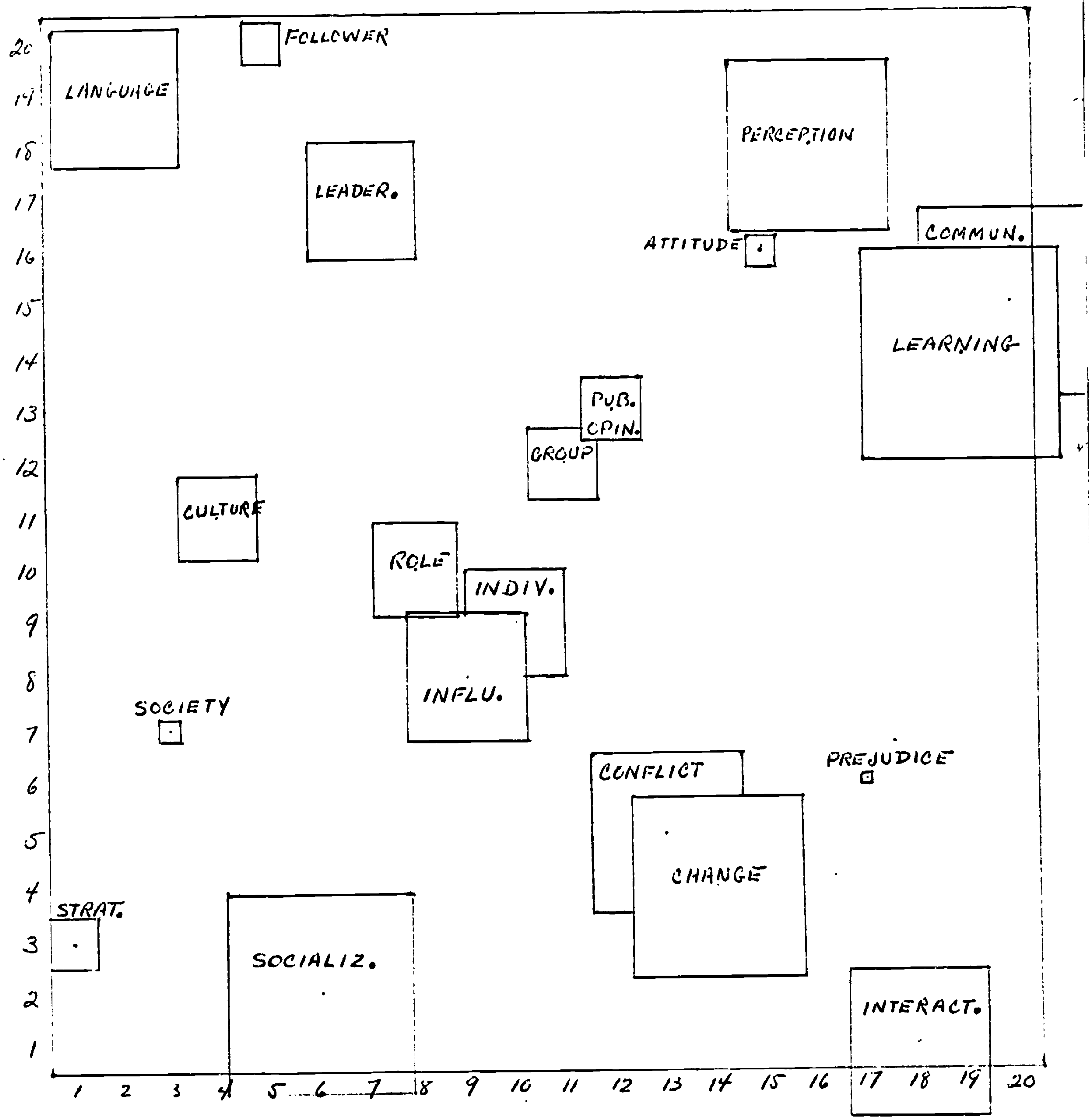


4TH DIMENSION:

LEARNING
ROLE
FOLLOWER
SOCIALIZATION
PERCEPTION
LEADERSHIP
PUBLIC OPINION
CHANGE
SOCIETY
INFLUENCE
GROUP
LANGUAGE
COMMUNICATION
ATTITUDE
PREJUDICE
INTERACTION
STRATIFICATION
CULTURE
INDIVIDUAL

STUDENT 207: 1ST TEST

COURSE GRADE . 3.84
MATCH WITH INSTRUCTOR'S STRUCTURE · MODERATELY LOW (.38)

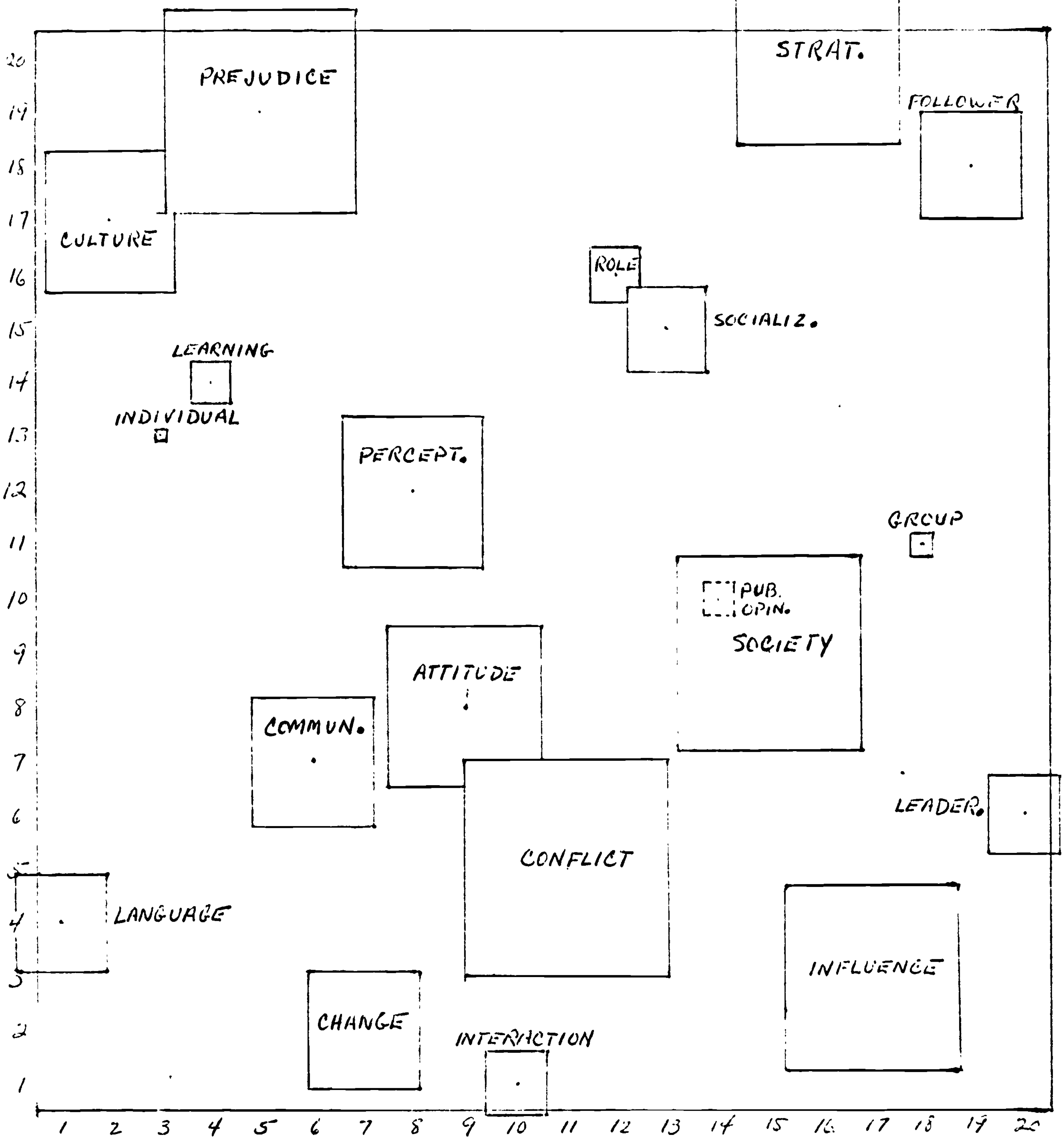


COURSE GRADE: 3.84

MATCH WITH INSTRUCTOR'S STRUCTURE: MODERATELY LOW

STUDENT 218. 2ND TEST

COURSE GRADE: 3.70
MATCH WITH INSTRUCTORS STRUCTURE: ~~[illegible]~~ HIGH (.65)



4TH DIMENSION

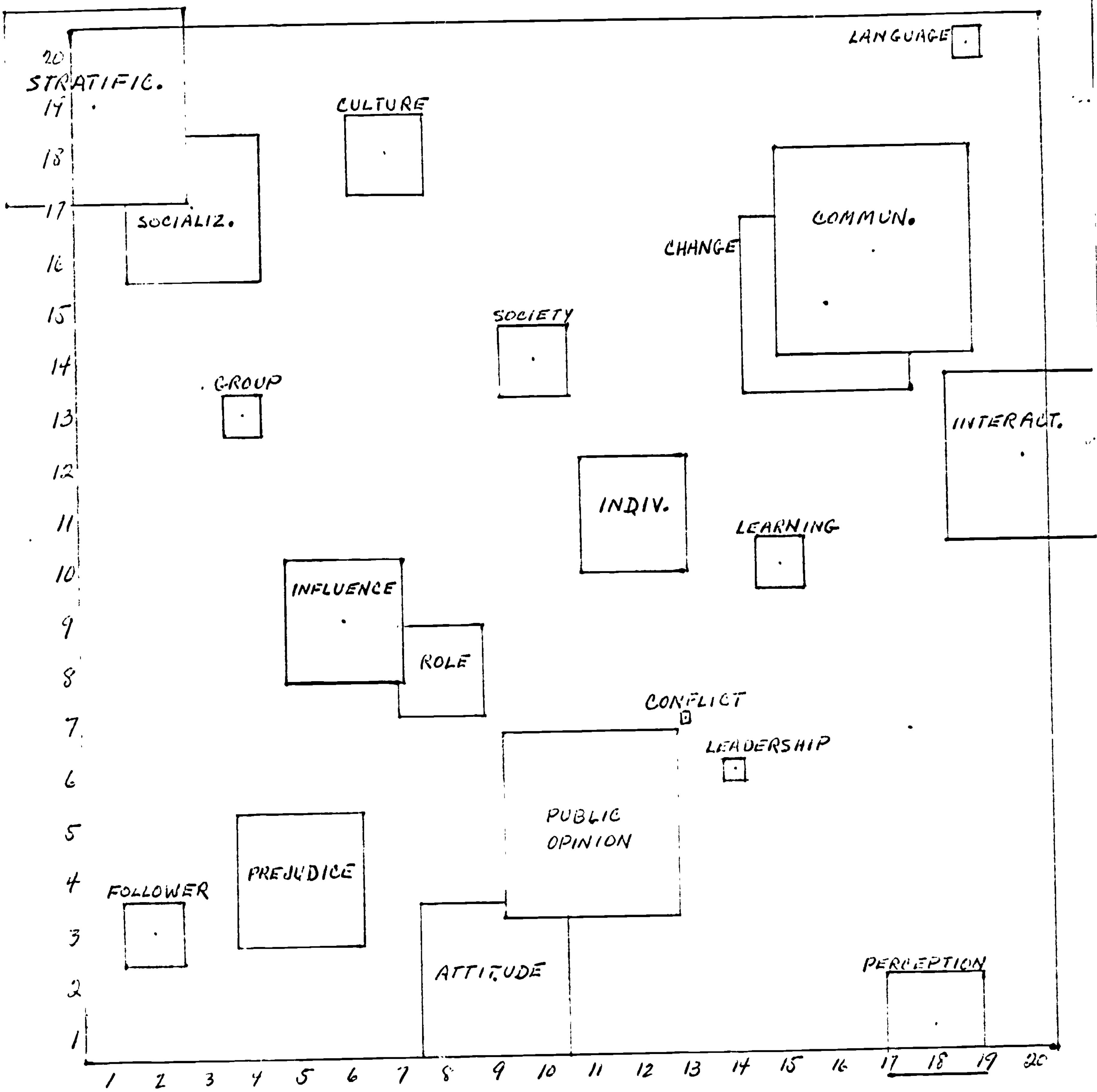
LEADERSHIP	
STRATIFICATION	INFLUENCE
CONFLICT	PUBLIC OPINION
COMMUNICATION	FOLLOWER
ROLE	PREJUDICE
INDIVIDUAL	PERCEPTION
CHANGE	LANGUAGE
GROUP	ATTITUDE
INTERACTION	LEARNING
SOCIALIZATION	CULTURE
	SOCIETY

5TH DIMENSION

LEADERSHIP	
ROLE	INFLUENCE
SOCIETY	PREJUDICE
CULTURE	FOLLOWER
LANGUAGE	COMMUNICATION
CHANGE	INTERACTION
PERCEPTION	STRATIFICATION
SOCIALIZATION	GROUP
LEARNING	CONFLICT
ATTITUDE	INDIVIDUAL

STUDENT 225 : 2ND TEST

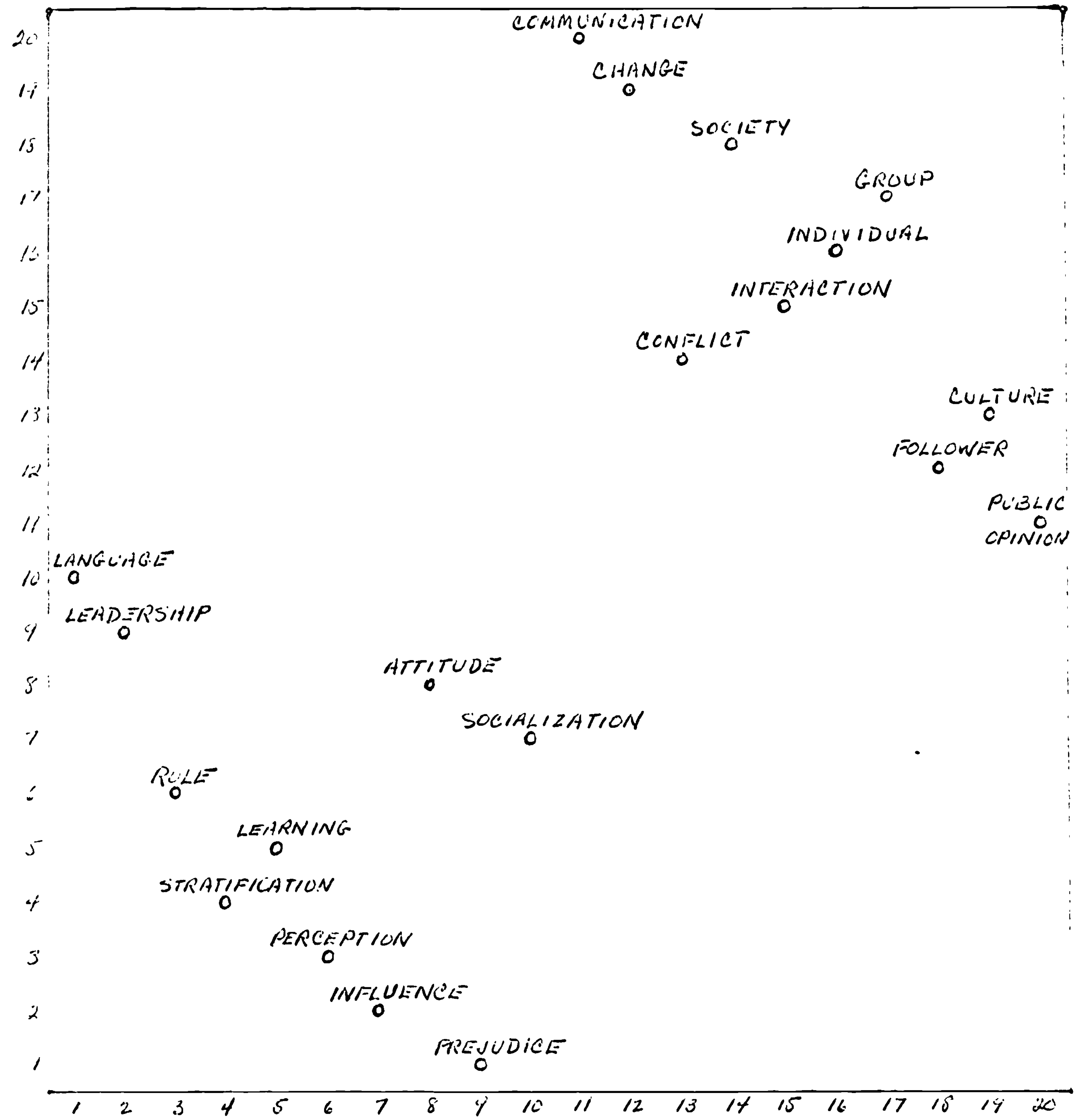
COURSE GRADE : 1.09
MATCH WITH INSTRUCTOR'S STRUCTURE: LOW (.33) 1ST
MODERATELY LOW (.41) 2ND



4TH DIMENSION
CONFLICT
COMMUNICATION
PUBLIC OPINION
LEARNING
GROUP
ATTITUDE
ROLE
SOCIALIZATION
STRATIFICATION
INFLUENCE
PREJUDICE
SOCIETY
CULTURE
LEADERSHIP
CHANGE
PERCEPTION
INDIVIDUAL
FOLLOWER
INTERACTION.
LANGUAGE

STUDENT SO1: 2ND TEST

COURSE GRADE. 1.77
MATCH WITH INSTRUCTOR'S STRUCTURE: LOW (.16 TO .24)



Discussion

The confirmation of the major hypotheses, that number of dimensions and agreement with instructor's structure vary with grades, suggests that the investigation has a piece of something, but the low correlations (.3 to .4) show either that the functional relationships are inherently weak or that there is considerable error variance uncontrolled. As might be predicted, I am sufficiently interested even in the weak findings to want to track down error variance.

Number of dimensions. Schroder, Driver, and Streufert (1967) state clearly the position of current complexity theory: that a person who has more ways of classifying and combining chunks of information in a particular area is able to deal more effectively - process new information, retrieve old information, or solve problems - with that area. They emphasize that this personal complexity, while it may be linked to general personality characteristics, varies considerably from one topical area to another, and with varying conditions of reward and punishment in the environment.

In this study, I have chosen to represent a cognitive area as a semantic field, given structure by the arrangement in it of chunks of information in the form of words. I would argue that every associative link is implicitly a (more or less) rudimentary theory which could be articulated by naming the relation underlying the link. Where these links are grouped into a chain, cluster, or dimension we have an implicit theoretical system, with extended and interlocking relations and internal analogies. The word "implicit" is crucial here, however, because there may be great differences in the degree to which any such theoretical system is susceptible of explicit statement and rational, discursive explanation. We may nevertheless expect that all the dimensions of a person's cognitive structure in an area will affect how he deals with that area. Differences in potential explicitness may well lie behind those curious discrepancies which, surely, every teacher has come upon, between a student's feeling of control over a subject and what he is able to articulate for formal evaluation.

This last point raises the usual questions about the meaning of course grades, our only dependent variable. Even disregarding the problem of inconsistency in grading standards, we may well ask whether our standards do not overemphasize verbal facility, to the disadvantage of intuitive understanding and originality. In this light, correlations of .3 to .4 may well represent a much larger proportion of the systematic variance than of the total variance. But that is only speculation.

A more mundane problem cropped up in the measurement of number of dimensions, typified by the student mentioned before who turned in a second matrix with a single, large +3 written across it. This is exemplified in general by the marked increase in the mean association values from the first to the second testing. Of course, greater acquaintance with an area will provide more potential associations among all of its parts. In other words, more relations are put to work in classifying the information, and this is what we mean by increased complexity. But in my study, where only a seven-point scale was available to register association, students tended to push their judgments to the top of the scale, thus cramming them into a smaller range. This in turn affects the factor analysis by reducing the differentiation among items and so reducing the number of distinct dimensions. Worse yet, the better the student, the greater his increase of associations, so our complexity measure gets washed out.

In the results reported above I attempted to correct for this by means of partial correlation, with some good effect. But this is at best patching. The relation of mean association to number of dimensions is complex because of the end-of-scale effect. A very large mean association value necessitates fewer dimensions, but mid-scale values may yield few or many dimensions, depending on their variance. It seems quite likely that the loss of significance of the correlation of dimension-number with grade from first to second testing is a result of the increased interference from the end-of-scale effect.

Reliability and matching. As noted above, the before-after comparison was a weak way of checking reliability. Since change was expected, normal reliability criteria could not be applied, but I did expect something on the order of .6 to .7, which was the matching level of my own first and second tests. Only one student reached that level, however, and the median value was only slightly above .4. Still more surprising, matching with my structure was substantially equal with self-matching.

The end-of-scale problem may be producing interference here too. The correlation between mean association value on the second test and the specific matching reliability was -.30. Systematically larger association values on the second test mean fewer dimensions available for matching, and the lack of differentiation in the matrix may make a structure much easier to tilt into a new set of dimensions by means of a few small changes in associations.

The similarity of the reliability and instructor-matching indices raises at least two questions. First, can it be that it is increased matching with the instructor that reduces the reliability? The relevant correlation, between change toward the instructor and reliability, is indeed negative, but only -.14. It is too small to solve the problem. Second, are we dealing with simply a general agreement as to the use of these words? The rather wide range of both the reliability and matching indices throws some doubt on this, but it is the best explanation I have to offer. The Mopsy program tends to play down "general factors", but where patterns of differentiation are similar, it will reflect that.

The correlation between instructor-matching and grades bears some discussion. In view of the instructor's fairly high reliability, it is surprising that matching with his second test is only related to grades in one instance, and not very strongly, while matching to his first test is consistently related to grades, whether comparison is by specific or total matching, or from the student's first or second test. This suggests that the instructor's initial categorization sets the framework of the course, and students are more or less able to make sense of the material on that basis. Alternatively, we might conclude that the instructor formed a basic impression of the student early in the course which was difficult to modify later on. Less cynical than either of those interpretations, and equally plausible, is the possibility that some cognitive structures are better matches than others for the "inherent" structure of the subject matter, and if so it seems reasonable to expect the instructor's structure to approach that ideal more closely than does the average student's. Clearly we need additional data to settle the locus of causality: perhaps a student's evaluation of his own understanding of the course would be of some help, as would some criterion matrices from specialists in the field other than the instructor.

An additional possibility must be dealt with for the matching vs. grades correlation. Number of dimensions has been shown to correlate positively with grades. Could the greater number of dimensions, by providing more chances for a good match, account for the correlation? The correlation between dimensions and matching on the first test is +.4, and on the second more than +.5, but when number of dimensions is held constant the matching vs. grades correlation is reduced by only one or two hundredths, remaining statistically significant. Apparently matching and complexity affect performance independently.

A last point on matching: I have made little mention of the distinction between specific and total matching, because they turned out to be nearly identical in distribution, and because the specificity ratio between them provided no significant correlations. Though the specific matching is intuitively more attractive to me, total matching is less trouble to compute.

The structural diagrams. The diagrams, though they are among the long-term goals of this line of research, must be approached intuitively at this stage. The statistics presented above are one attempt to get a grip on the structures and their functional relationships to formal learning. At the moment we can simply ask that they "make sense", and, in varying degrees, I think they do. I have found that a number of dimensional labels, such as "cognitive-social", "psychological-sociological", "adaptive-receptive", "fixed-fluid", "abstract-concrete", "static-dynamic", and "nomic-anomic" seem repeatedly appropriate. No doubt the reader will think of other labels. But in the long run the important objective is to gain an understanding of the student's construct and its functional relations.

Conclusions, Implications, Recommendations

This study offers two kinds of conclusions:

1. Methodological. It appears that the Matrix Optimizing System offers a plausible alternative to parametric methods of factor analysis, since it makes fewer assumptions about the data, runs far more rapidly on a computer, and may for some purposes offer a richer or more concentrated data description than do the accepted methods. By making this method available upon request I hope to learn more about its useful applications and shortcomings, and to learn whether a rigorous rationale is available for it.

2. Substantive. Two major hypotheses were confirmed insofar as the relations were greater than one would expect by chance, but at relatively low levels of correlation. It was shown that students whose associative matrices yield a larger number of dimensions under nonparametric factor analysis, tend to get higher grades in the course, as would be predicted from current complexity theory. Second, it was shown that students whose cognitive dimensions matched those of the instructor tended to get higher grades in the course. But the findings were static. None of the measures of change of structure was found to be related to course performance.

An end-of-scale effect in the association judgments produced considerable interference with the results, especially the "after" measures. It is apparent that this will have to be corrected before relations strong enough to be useful can be found.

In order to improve the method and design, I propose the following changes: (1) Remove the end-of-scale problem by specifying a distribution to which the association judgments must conform. The obvious choice here is a rank ordering of each row, with the highest value given to the word most closely associated with the head word of the row. (2) Use fewer subjects and get more matrices from each - perhaps five in one term. This will allow a closer check on reliability and throw some light on the gradual processes of change. (3) Add more dependent variables. Course grades are worth using, but they should be supplemented by such measures as instructor's judgments of students' originality, and students' statements of both feeling and understanding about the instructor and different books in the course, all of whose associative structures can be derived for comparison.

All of this proposed follow-up of findings which accounted for only 10-15% of the variance in the dependent variable may seem risky. But in my opinion the value of a systematic but rich method of describing associative structure and predicting its effects in an educational setting is so great as to justify following up anything that offers consistent and statistically significant results, however small.

Summary

This study tested whether the associative structure of individual students could be used to predict their performance in a particular course. Twenty representative terms in social psychology were presented to students in two sections of an introductory course and their instructor, with the request that they assign associability scale values to all possible pairs of terms. The matrices were then factored by a new, nonparametric method which yields rank-ordered dimensions.

The two main hypotheses, that course grade varies with number of dimensions, and that course grade varies with agreement with the instructor's structure, were both confirmed, but with correlations only in the .3 to .4 range. Subsidiary hypotheses linking performance to size and direction of change in structure and to specificity of matching with the instructor's structure all failed. It appeared that considerable interference came from end-of-scale effects in the associability judgments.

Further study of this area seems worth while, in view of the significant though weak findings. In future research, the associability judgment scale should be improved by prescribing the score distribution, larger amounts of data should be collected on fewer students so that a detailed analysis of the change process is possible, and further dependent variables, such as students' feelings about and degree of understanding of the instructor and of different books, should be added.

Evidence was presented in an appendix of the usefulness of the new nonparametric factoring method, by means of comparisons with standard parametric solutions.

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Appendix A

Mopsy : The Matrix Optimizing System

A useful factor analytic tool must reduce and abstract from the data in such a way that its basic, internal relationships are made clear. This is a complex requirement. Any factor analytic method, of course, boils down a matrix, but two problems then arise. One is that frequently a process of spinning out takes place, by which a large number of factors are generated. Beyond a certain number, these no longer clarify the data, but become in their turn a problem. Reports of factor analysis results commonly label one or more of the resultant factors "uninterpretable", or as due to error variance, or, worse, name factors with uninterpretable names or by listing their high values. Oddly enough, these difficulties seem to arise from the mathematical precision with which the factoring operation is defined, so that it is able to extract results below the level of error variation in the matrix. Unfortunately, it has been difficult to decide objectively when the factoring should stop.

The second problem is related to the problem of interpretability. All the standard factor analytic methods put out sets of points located on arbitrary dimensions. In order even to attempt interpretation, the axes must be rotated, and the various available criteria for rotation, though clearly definable and repeatable, are simply different attempts to define mathematically a result that looks good on graph paper. My colleague, David Beardslee, who has had occasion to work extensively with factor analysis results, tells me that he has seen several sets of data for which the varimax and quartimax (the two most popular rotation methods) results were different, and that furthermore their results are sensitive to the starting point of the rotation. Indeed, some programmers have introduced initial random rotations into their factor data in an effort to break up the effects of particular starting points. Rotation, then, appears to add a further imponderable to the already vexing problem of multiple factor interpretation.

All of this is serious enough with input consisting of correlation coefficients with a high degree of accuracy based on large samples. My data is on individuals; it is therefore fragile and filled with error. If I use an elephant gun on a mouse, I may not be able to find the mouse to tell whether I've hit it. What seems to be called for instead is some sort of non-parametric factor analysis, which will not pretend that the data is more exact than it is.

I was led to my proposed solution of this problem by consideration of the traveling salesman problem: how to visit all the points in a fully connected network and return home, all by the shortest route. (I understand that no rigorous solution exists for that problem.) I was not concerned with the return home, however, wishing rather to find the shortest path from one "end" of the set of points to the other. An association matrix may be regarded as isomorphic to a set of points with their closeness (rather than distance) represented at the intersections of the rows and columns. The matrix entries must all be positive, but a correlation matrix with negative numbers may easily be rescaled. What we want is a reordering of the matrix so that the highly associated words are near each other in the order, with the result that the high values in the matrix are found near the diagonal and the low ones in the corners. In order to achieve this I treat the association values in a row as weights along a rod and calculate the center of gravity. I then reorder the matrix by ranking the centers of gravity, repeating the whole process until the order stops changing.

It's not quite so simple as that. In order to prevent irreducible and meaningless oscillation, diagonal values must be set equal to the largest value in the row, and in order to prevent a certain class of false optimal solutions the matrix must be started as a 2 x 3 and gradually increased to n x n, starting with the rows having the highest sums and working down.

The output of the program is a rank order that represents the projections of a set of points onto a "best" axis drawn through them. The axis will tend to be drawn between extreme "corner" points in the space, but may not if the "tilt" of points nearer the center is sufficiently strong. What we seem to have, then, is Factor I, already rotated. When applied to a word association matrix or a correlation matrix, the program turns out an order which is subjectively meaningful.

Before describing the process of defining further dimensions, let me comment on the problem of rigor. I have been unable to define rigorously what I am doing. My colleague William Hammerle, of the Engineering School, was able to show that a rigorous ordering can be provided <u>if</u> one allows it to be interval scaled, but that the proof may not hold for an ordinal scale. Unfortunately, the accompanying algorithm requires the solution of n-1 sets of equations, having <u>each</u> n-2 equations in as many unknowns (where n x n is the size of the matrix). Hammerle believes that it would be possible to reduce this requirement somewhat by further analysis, but the probable high cost in computer time and the necessity of accepting an interval scale output led me to decide in favor of the strictly pragmatic approach, which seems to have good empirical justification. Hammerle's approach did show me, nevertheless, that the ordering process should be limited to symmetric matrices. The program is designed to handle nonsymmetric input matrices by averaging the corresponding upper and lower triangle values.

To find a second and further dimensions, we need a process for extracting from the matrix the results of the first ordering, remembering to make no assumptions about statistical distribution within the matrix. To do this, I find the actual frequency distribution and, as it were, deal it out, high values first, starting with the centermost off-diagonal ($r_1 c_2$, $r_2 c_3$, ... $r_{n-1} c_n$) and working out. From each cell I subtract the lowest distribution value assigned to that off-diagonal, changing negatives to zero. (To keep the negatives is tantamount to assuming that the first order is an equal-interval scale, which, in general, it is not.) Then the process is repeated with the residuals.

Empirical tests on sample distributions of points in 2- and 3-dimensional spaces showed good results both by eye and by correlations between input associations and output distances on the order of -.9 (the negative sign because association and distance are opposites). However, when data consisting of associative overlap scores or associability scale judgments was used as input, the interpretability remained high but the input-output correlation dropped - to .6 for overlap scores and in some cases to .3 for scale judgments. Worse yet, the stopping rule that took effect when the correlation ceased improving with added dimensions often cut off meaningful dimensions in the data.

After a good deal of trial and error, I established a purely internal criterion, based on the tendency of the program to find successive orthogonal dimensions. The argument is that as long as a new, independent ordering can be found there is still information in the matrix, but when orderings are like earlier ones, little new information is being added. To translate this into a practical stopping rule, I treated each new dimension coming out of the analysis as having a somewhat higher marginal cost. Factor analysis, after all, is supposed to simplify data. The cost function was defined as follows: when the sum of squares of rank order correlations between the last dimension and all previous ones, multiplied by the number of dimensions, is equal to or greater than 1, the cost of throwing away information is less than the cost of adding a dimension, and the last dimension is discarded. To give some feeling for the operation of this criterion, the following table shows, for each dimension number, the single correlation and the average correlation, either of which will, if equalled or exceeded, cause factoring to cease:

#	Single	Average
2	.71	.71
3	.58	.42
4	.50	.29
5	.45	.23
6	.41	.19

Driver (1962) suggested that uneven weighting of dimensions indicates a low level of complexity. Since uneven weightings in Mopsy cause repetition of information, Mopsy should cut off sooner on low-complexity matrices, where parametric analysis would find more factors.

The Mopsy program is available on request at the Psychology Department, Oakland University. It is written in IBM Symbolic Programming System for the IBM 1620 with 40,000 decimal digits of core storage, on line printer, and disk packs. On that apparatus, running time in minutes is approximately $n^2/100$, where n is the matrix size. Complex data may run up to 25% longer.

Since this method is not rigorously defined, it must depend on its own output for justification. The figures on the succeeding pages are Mopsy output for sets of data already subjected to parametric factor analysis by other investigators.

Figure 1 shows the Mopsy solution for Thurstone's (47) Box Problem. Thurstone's solution, as might be expected, comes up with three dimensions, X, Y, and Z, or length, width, and depth. Note that the Mopsy solution represents the relations among these measurements as a triangle in a plane. Thurstone finds it convenient to graph his results in a plane, too, and when he does the resulting diagram is almost identical with Figure 1. This points up the fact that Mopsy solutions tend to find the just-sufficient number of dimensions rather than a larger, absolutely "correct" number.

Figure 2 gives the Mopsy solution for Harman's (16) physical measurements problem. Like the principal-factor solution, Mopsy finds two clusters. The existence of a general factor, which Harman calls "growth", is expressed by Mopsy as a correlation between the first and second dimensions.

Figure 3 gives the Mopsy solution for Harman's (16) emotional traits problem. The principal-factor solution gives a "general emotionality" factor, which I find meaningless, and a second factor, almost identical with Mopsy's factor I, which Harman calls "egocentrism". I would characterize the Mopsy solution as follows: Factor I: not-acted-upon vs. acted upon; Factor II: acting vs. not acting; Factor III (obviously) good vs. bad. Harman's "general emotionality" could be described as the nearness to the center of the Mopsy diagram.

Figure 4 is the Mopsy solution for Harman's (16) political variables problem, based on the traits of voting districts. He finds two factors, "Traditional Democratic Voting" and "Home Permanency". I would suggest labeling mine Social Class (I) and something like "Identification with the local community" (II). It is hard to judge between these - the preference would depend on what one could do conceptually with the two formulations.

The OSS assessment variables (36)are represented in Figure 5. The original parametric solution for that matrix produced four factors: Adjustment (emotional stability, social relations, security), Effective Intelligence (effective intelligence, observing and reporting, propaganda skills, over-all), Physical Energy (energy and initiative, leadership, physical ability), and Authoritative Assertion (energy and initiative, leadership). Motivation for assignment had no high weightings, but came closest to Adjustment. The Mopsy solution displays all those groups, but in two dimensions, apparently cognitive-noncognitive (I) and internal-external (II).

The examples displayed here demonstrate, I think, that Mopsy output makes sense, but that it is different from parametric factor analysis output. While it may be the case, as I have argued, that the factors come already rotated, as it were, the Mopsy diagram doesn't look like "simple structure." Because the rank ordering insists on uniform spacing in the distribution, the points spread out over the whole space rather than forming the typical tight clusters of parametric analysis. Personally, I find such a spacing easier to work with. What is most valuable, I feel, are the topological relationships among the points; absolute distances are much harder to interpret, and less reliable.

In any case, I hope that other people will see fit to try out this method. Perhaps someone will be able to demonstrate rigorously why it works and what its faults are.

THURSTONE'S (1947) BOX PROBLEM (p 370)

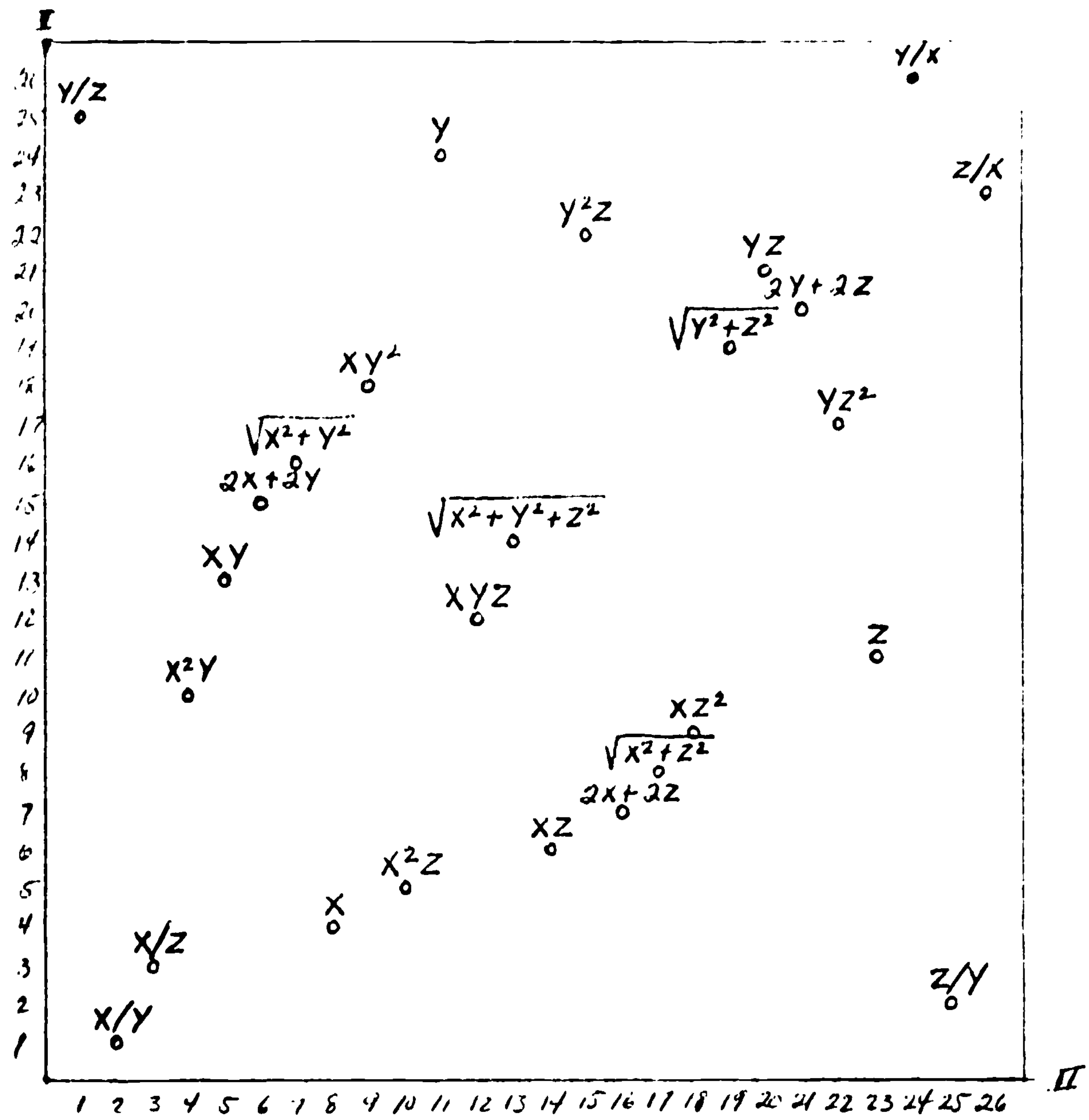

FIGURE 1

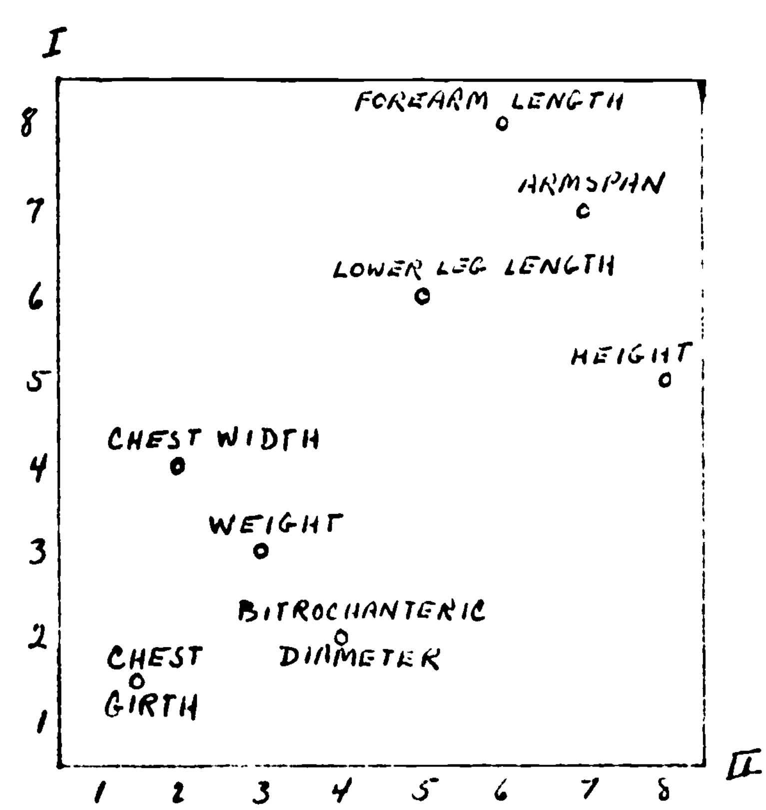

FIGURE 2: HARMAN (1960): EIGHT PHYSICAL VARIABLES

(pp 82, 172-173)

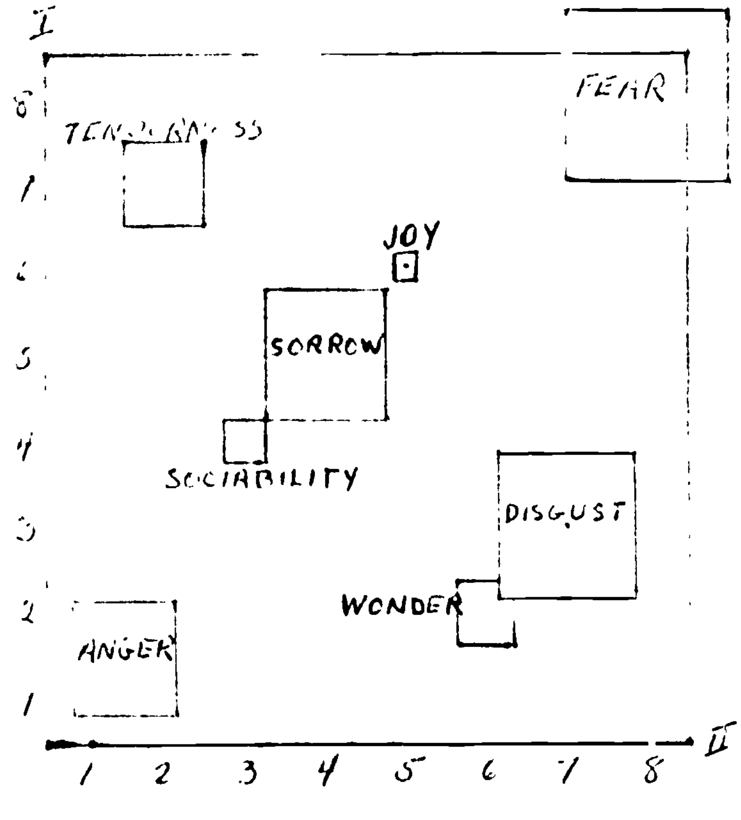

FIGURE 3: HARMAN (1960).

EIGHT EMOTIONAL TRAITS (p.176)

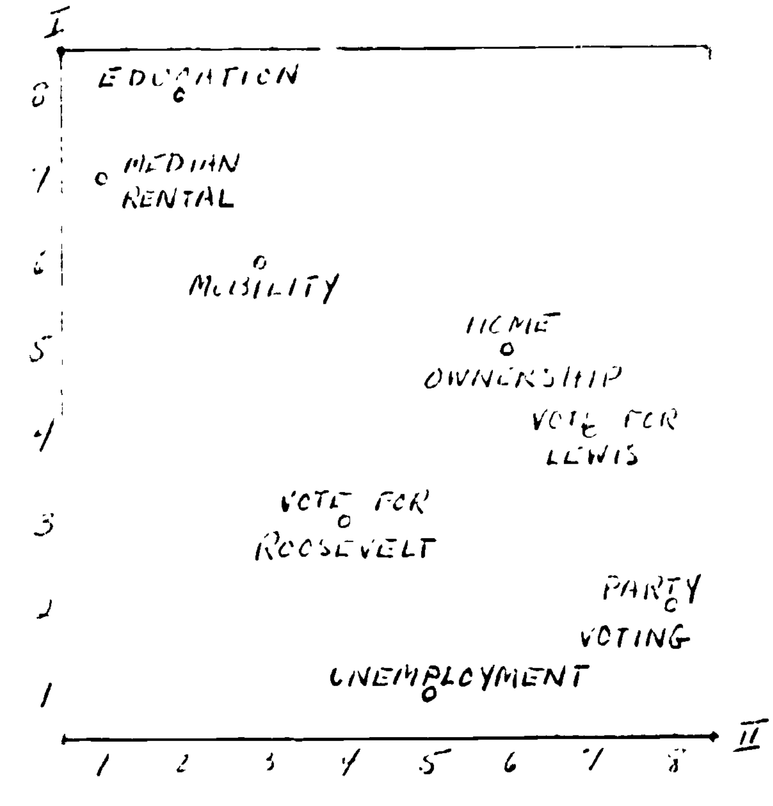

FIGURE 4. HARMAN (1960)

EIGHT POLITICAL VARIABLES (p.178)

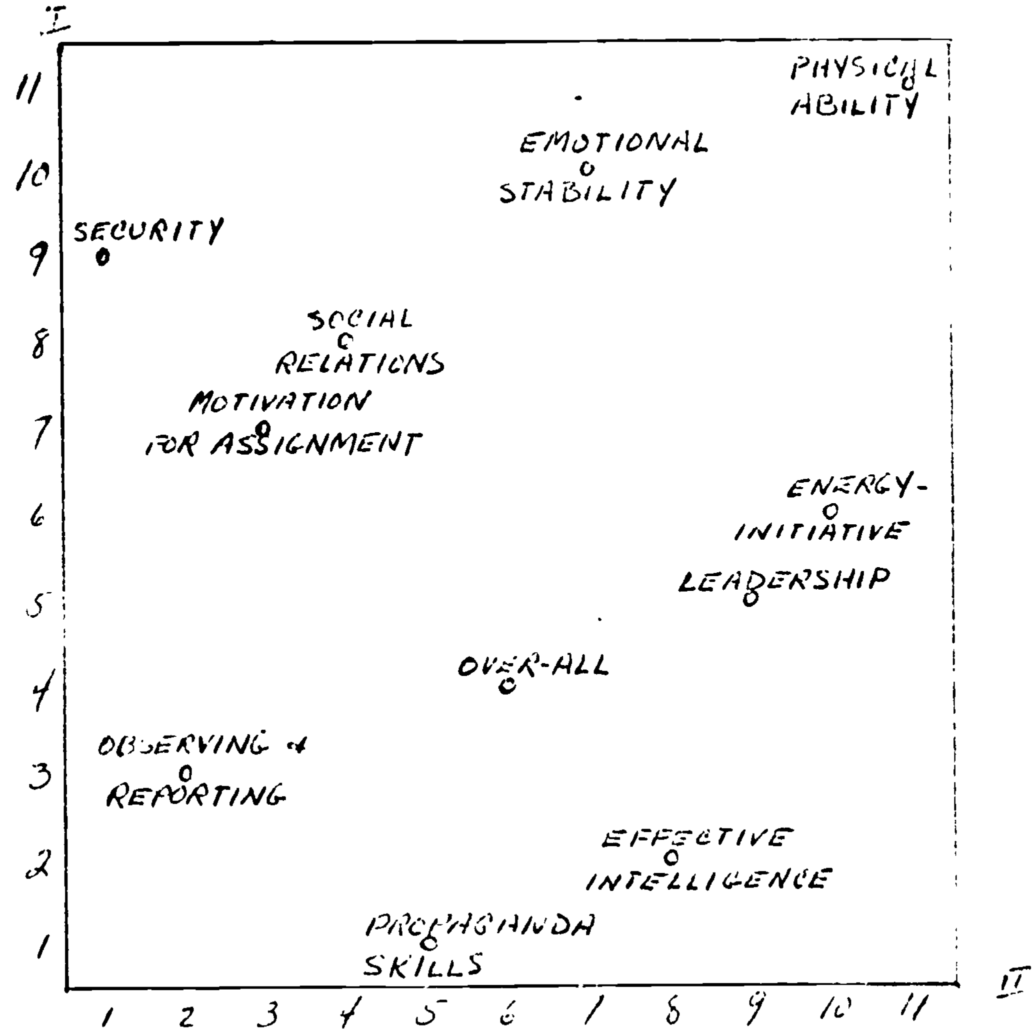

FIGURE 5: OSS ASSESSMENT STAFF (1948):

ASSESSMENT VARIABLES (p.511-513)