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ABSTRACT

Multidimensional scaling methods were used to derive interpretable models of medical school similarity with respect to research and graduate medical education intensiveness. On the basis of cluster analysis, private schools seemed to be categorizable into those that are relatively intensive on both research and graduate medical education, those that are not intensive on either, and some that, along with some public schools, are both extensive (in absolute measure) and intensive (in relative measure) on graduate medical programs. These groups are readily apparent in the scaling model, but graduations of difference within groups are also apparent. The public schools showed similar separability along continuous dimensions of difference. The statistical analyses are discussed at length. (Author/MSE)

A MULTIDIMENSIONAL MODEL OF MEDICAL SCHOOL SIMILARITIES

FINAL REPORT

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A MULTIDIMENSIONAL MODEL
OF MEDICAL SCHOOL SIMILARITIES

Charles R. Sherman, Ph.D.

FINAL REPORT

<u>*RELATED STUDIES*</u>

A Second Exploratory Analysis of the Relations Among Institutional Variables

An Empirical Classification of U.S. Medical Schools by Institutional Dimensions

Division of Operational Studies

ASSOCIATION OF AMERICAN MEDICAL COLLEGES

March 1977

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

A Multidimensional Model of Medical School Similarities is one of five studies performed in 1976 by the Association of American Medical Colleges (AAMC) to examine the characteristics of U.S. medical schools and the interrelationships among variables that describe them. Two of the five studies are replications of previous work. This report is one of three that present fresh explorations of AAMC's extensive base of institutional data.

Multidimensional scaling methods were used to derive interpretable models of medical school similarity with respect to research and graduate medical education intensiveness. Two- and three-dimensional models of both public and private medical schools using both metric and non-metric scaling procedures were derived. Two-dimensional "metric" models of public and private schools were presented in the form of spatial "maps". The relative merits of several models were discussed.

The imposition of a cluster analysis model of medical school similarities with respect to six factors onto the multidimensional scaling model for two factors seemed to enhance the interpretation of both models. On the basis of cluster analysis, private schools seemed to be categorizable into those that are relatively intensive on both research and graduate medical education, those that are not intensive on either, and some that, along with some public schools, are both extensive (in absolute measure) and intensive (in relative measure) on graduate medical programs. These groups are readily apparent in the scaling model, but gradations of difference within groups are also apparent. The public schools showed similar separability along continuous dimensions of difference.

The models of similarity derived and compared in the present study are simplifications of the information contained in data provided by the medical schools and the NIH's records of grant applications. The validity and usefulness of the models must now be assessed by individuals with an informed familiarity with many schools.

Chapter I

INTRODUCTION

Each of the 117 accredited medical schools in the United States is unique. There are many ways in which they differ from one another. Two schools having nearly the same enrollment and degree of research involvement may yet differ significantly in the extent of their involvement in graduate medical education, in their orientation toward meeting state or national needs, in their systems of financial management, and in many other ways. Acknowledging these differences does not diminish, however, the occasional need to take the other perspective and to identify schools that are most similar to one another. A dean encountering a new management problem may wish to identify and consult the dean of another school most like his own with respect to certain characteristics relevant to the problem. A researcher conducting a survey of a sample of schools may need to identify one additional school to best substitute for a sampled institution that may be unable to respond. A new staff person in a government agency or philanthropic foundation dealing with medical schools may benefit from a visual aid that helps him or her to learn for the first time about all medical schools and how they are different from and similar to one another.

This report describes the use of multidimensional scaling to create a map-like "model" to meet these and similar needs.

Overview

In previous studies conducted by the Association of American Medical Colleges (AAMC), it has been found that research emphasis and graduate medical education emphasis were reliably observable and independent dimensions of medical school differences. In preliminary steps of the present study, a series of small factor analyses led to the selection of twelve available measures related to one or both of the two conceptual dimensions. Care was taken to avoid measures of simple institutional "size". A Euclidian distance formula was used to compute numerical indices of the similarity (or dissimilarity) of all possible pairs of school profiles on the 12 measures. Public schools and private schools were analyzed separately. Each complete matrix of similarities was submitted to a multidimensional scaling computer program resulting in a "map" of schools, where distances between schools on the map correspond closely with the indices of similarity computed between pairs of profiles. The meanings of several directions on each map were identified with the aid of multiple regression and a selection of institutional variables.

A comparison was made between the results of "metric" and "non-metric" multidimensional scaling, two scaling methods that allow for different assumptions to be made about the properties of the similarity index used.

Public and private school models were compared on their degrees of apparent suitability in simplifying 12 measures with only two dimensions. Some comparisons were also made with models having three dimensions.

Finally, the results of a cluster analysis of medical schools, performed with respect to six basic dimensions of difference, were imposed on the two-dimensional spatial models. The result was an improvement in the ease of interpretation of both the scaling and clustering models.

Models of Similarity

There are several ways to create a model to represent the similarities and differences among a set of medical schools (or any other measurable objects or, even, less well defined concepts). Modelling, generally, results in a simplification that may nevertheless be adequate or suitable for some purposes. A very simple model is prepared by conducting one measurement (e.g. counting students) at each school, and ordering the names of the schools according to the rank of their measured values. Schools having similar ranks and listed near one another are then considered similar with respect to the property that was measured. A less crude model (although possibly less accurate if the measures are only approximate guesses) would result from drawing a linear scale from zero through one thousand and writing the names of the schools at the point on the scale corresponding to its measured value (again, say, numbers of medical students). A more crude model than simply rank ordering all schools would be to group them according to some criterion, such as "small" (less than 99 first-year students), "medium", and "large" (more than 150 first-year students). The information conveyed by the three lists constituting the last model would obviously be less than the information carried in the first two models, but the model may be suitable for some needs, and indeed roughly accurate if the distribution of first-year class sizes were cooperatively trimodal.

Before describing more complicated models, it may be worth noting that some models may be good approximations or substitutes for others. Since class size is known to be correlated (albeit not perfectly) with age of an institution, the groupings of "small", "medium" and "large" may serve as a suitable substitute for "young", "middle-aged" and "old" if exact founding dates were unknown.

More complicated models of similarity may be necessary when the concepts defining the similarity are more complex, for example, the similarity of medical schools with respect to numbers of medical students and basic science graduate students. A simple ranking, scaling or grouping of schools on the sum of the two counts may be of little meaning or value.

A scatter plot of school names between coordinate axes corresponding to the two separate student counts would be more interesting and convey much more information. Schools plotted close to each other would be seen as "similar". A simpler model would result by assigning each school to one of nine groups according to large-medium-small on both measures. If one group contained no school names (e.g. relatively small counts of medical students and large numbers of Ph.D. students) the model would be even simpler (8 instead of 9 groups) yet would be just as accurate in representing two long lists of numbers. Again, schools listed together may be regarded as similar with respect to the two measures, and possibly with respect to other correlated measures.

Multidimensional scaling and cluster analysis are two methods of creating simplified models of medical school similarities when the similarity measures are derived from selections of several measures on which schools vary. Clustering results in groupings of schools found to be similar within groups and dissimilar between groups, according to a mathematical criterion. Scaling produces a map of schools, having a usefully small number of dimensions, where distances between schools on the map correspond closely to the measured similarity between schools. Scaling allows for continuous gradients of difference in a space of possibly reduced dimensionality, while clustering represents empirical grouping, without gradation, in a space of full dimensionality.

Multidimensional scaling was developed within the discipline of psychology where it was originally applied in studies of perception and cognition. In psychology, judgements of similarity were the raw measures and were of uncertain quality. Whereas the original, or "metric", scaling methods required strong assumptions about the quality of the measures, a more robust method has been developed. "Non-metric" multidimensional scaling requires that the similarity measures have only ordinal accuracy (a requirement more easily met than ratio accuracy), but it requires significantly more computational effort. Since the similarity index derived from the data used in the present study was previously untested in the context of scaling medical schools, both scaling methods were tried in the development of models of medical school similarity.

One previous application of a multidimensional spatial configuration to model medical school similarities appears in the literature of higher education. Using data from the 1969-70 "Medical Education" issues of JAMA, Rogers and Elton(1974) modelled the similarities of 86 medical schools with respect to three derived factors: undergraduate medical enrollment, public versus private, and postdoctoral basic science enrollment.

Chapter II

METHOD

Methodological considerations in this study include the selection of data and medical education institutions to be analyzed, the computation of indices of similarity between those institutions with respect to the selected measures, and the scaling algorithm used to map schools into a spatial configuration that can be visualized, i.e. to produce a model of medical school similarities. Multiple regression methods were also used to aid in the interpretations of the derived models. The following sections discuss each of these considerations in detail.

Data Selection

Since the concept of similarity is usually made with reference to some property or characteristic (even though that characteristic may not be rigorously defined), care was taken to select institutional variables that were related to two underlying concepts: the degree of emphasis each school places on research and the relative extent to which each undergraduate medical school is also involved in graduate medical education. In several factor analytic studies of wide varieties of medical school variables, these two concepts consistently emerged as apparently independent characteristics of U.S. medical schools (Keeler, et al, 1972; Sherman, 1975; Sherman, 1976; Sherman, 1977). Variables shown in the most recent study to be related to one or both of these constructs were initially considered for use in the present demonstration of multidimensional scaling. Variables known to be related to overall "size" of an institution (total revenue, number of medical students, number of housestaff, number of faculty and number of research grants received) were excluded since the focus of the study is on relative emphasis rather than extent of research and graduate program involvement. It was felt that "size" measures would dominate and unbalance the model. A principal components analysis gave assurance that 12 selected variables were related to aspects of two underlying dimensions of difference. Adding six "size measures" to the analysis resulted in three distinct underlying components, the first being institutional size, leaving nearly unchanged the loadings of the other variables on the other two principal factors. As discussed in another paper (Sherman, 1977), total revenue was found to be related to research emphasis, but it was more strongly related to overall "size" and therefore not selected to be used in the present study.

The twelve variables selected were:

(1) Ratio of housestaff (interns and residents) to undergraduate medical students,

(2) Ratio of medical students to full-time faculty,

(3) Percentage of living graduates (MD recipients) in general practice,

(4) Average salary of strict full-time associate professors in basic science departments,

(5) Mean standardized priority score assigned by NIH Initial Review Groups to applications for single investigator (R01) research grants,

(6) Percentage of part-time and full-time faculty holding M.D. degrees,

(7) Ratio of basic medical science graduate students (Ph.D. and M.A.) to undergraduate medical students (M.D.),

(8) Ratio of basic medical science graduate students (Ph.D. and M.A.) to full-time faculty in basic science departments (this variable was not used in previous factor analyses),

(9) Percentage of total funds expended for sponsored research,

(10) Percentage of total funds received from federal sources (including the recovery of indirect costs),

(11) Percentage of funds expended for administration and other general expenses, and

(12) Rate of approval of competing applications for NIH single investigator (R01) research grants.

The first six variables are more strongly related to a graduate medical orientation; and the second six are more strongly related to a research orientation. The means and standard deviations of the 12 measures are presented in Table 1.

The data were extracted from the AAMC's Researchable Data Base. Specific sources of data and computation formulas for each variable are described elsewhere (McShane, 1977a).

Table 1

Means and Standard Deviations of Variables
Used in Construction of Models of Medical School Similarities

		PRIVATE	PUBLIC	ALL		
		MEAN	MEAN	MEAN	ST.DEV.	N
STC043	RAT: HOUSESTAFF TO UNDERGRAD MD-STUD	.97	.72	.83	.72	114
INC058	RAT: MD STUDENTS TO FT FAC	1.66	1.84	1.76	.84	113
VAR388	AV SALARY - SFT ASSOC PROF BASIC SCIENCE	24.85	24.66	24.84	2.87	104
STC105	% LIVING MD-ALUMNI IN GENERAL PRACTICE	12.91	16.00	14.29	7.19	98
VAR352	IMPAC: MEAN STD P-SCR - R01 APP	.03	.13	.08	.33	107
FAC001	% PT & FT SAL FAC WITH MD	68.29	60.11	62.92	12.12	114
STC045	RAT: BMS GRAD-STUD TO UNDERGRAD MD-STUD	.23	.23	.22	.18	114
INC061	RAT: BMS GRAD-STUD TO BAS SCI FT FAC	1.09	1.36	1.23	1.09	113
INC017	% TOTAL EXPD FOR SPON RESEARCH	28.19	18.93	21.78	12.22	111
INC007	% REV FROM FED SOURCES & RCOV INC COSTS	43.91	32.74	37.32	13.17	106
INC026	% EXPD FOR ADMIN & GENL EXPENSE	9.97	9.88	10.33	5.71	111
INC045	IRG APPROVAL RATE OF NIH R01 COMP APPS	73.83	73.37	69.01	21.94	114

- 7 -

Data were available for at least 11 of the 12 measures for 102 of the 117 U.S. medical schools. The 15 schools excluded from the present modeling effort for lack of data were Baylor, North Dakota, South Dakota, Hawaii, California - Davis, SUNY at Stony Brook, Nevada, Missouri at Kansas City, Southern Illinois, Minnesota at Duluth, Mayo, Eastern Virginia, Wright State, University of South Carolina, and Uniformed Services. (Most of these schools are new.) In the few remaining cases of missing or obviously erroneous data, mean values of available data were substituted. The 102 schools used included 44 private schools and 58 public schools.

Index of Similarity

An index of similarity was computed separately for every possible pair of public schools and every pair of private schools. The similarity between two schools was defined as the square root of the sum of squared differences between the two schools' values for each of the 12 standardized measures. This is simply a 12-dimensional analog of the familiar two-dimensional formula for the length of the hypotenuse of a triangle: $H = \sqrt{A^2 + B^2}$. In the present case, the 12 "legs" are the differences between two schools' values of the 12 variables after each variable has first been "standardized" to have a mean of zero and a standard deviation of one. (Standardization removes the effect of having different units of measure for different variables.) As a result, two schools with nearly identical values on all 12 measures would have a dissimilarity index near zero. Two schools with very different values would have a large index of dissimilarity. (The indices may be conceptualized as distances in 12-dimensional space. Such a space, however, is impossible to visualize. The purpose of the multidimensional scaling model is to represent, as well as possible, the 12-dimensional space in a smaller number of dimensions that can be readily visualized.)

Multidimensional Scaling

Metric multidimensional scaling is a computational algorithm that accepts an N-by-N symmetric matrix of similarity (or dissimilarity) measurements between all pairs of N objects, and produces a set of spatial coordinates for each of the N objects. The mathematical underpinnings of metric multidimensional scaling are detailed in Torgerson (1958) and explained in more general language in Nunnally (1967). Basically the input matrix of distances is transformed and then factored by the principal axes method. In metric multidimensional scaling, the distances must be established on a ratio scale of measurement, e.g. a dissimilarity index with a value of 4 must represent twice the dissimilarity between two objects which have an index of 2. This is a rigorous assumption, especially in cases where overall similarity is judged directly. There is also a more recently developed method, non-metric multidimensional scaling, that requires only ordinal assumptions be made of the dissimilarity measures, i.e. that an index of 4 be recognized only as larger than an index of 2 (Shepard, 1962).

In the present study similarity matrices for public and private schools were submitted to both metric and non-metric procedures. The non-metric scaling program used was POLYCON developed by Young (1972). Using both methods, the matrices were scaled into 3 dimensions and into 2 dimensions. Thus, 8 models of medical school similarities were developed and compared. Two of these models are presented in the next chapter.

Regression

The major axes used to plot the "locations" of each school are not intended to be interpreted (as are the principal axes after rotation in factor analysis). The locations of the schools relative to one another are the object of multidimensional scaling. The configuration of plotted points can be rotated on the page without changing the model. If some of the many possible directions on the spatial map have meaning, they are revealed by subsequent subjective or objective analysis. A person thoroughly familiar with many of the schools could subjectively identify the common characteristics of schools in the upper-left side of the map, say, as distinguished from schools in the lower-right area. A more objective (though not necessarily better) method is to draw a vector on the map that best represents known institutional variation with respect to a particular measure. This is accomplished by using the (two or three) spatial coordinates as predictor variables and an external variable of interest (or several, but one at a time) as a criterion variable in a regression model.

The b-coefficients of the derived regression equation may be used as coordinates of one point on a vector passing through the origin of the space. The vector represents the direction of best fit in the space. The multiple correlation coefficient describes the degree of that best fit. Perpendicular projections of school locations onto the vector (or any line parallel to it) correlate with the criterion variable to the degree indicated by the multiple correlation coefficient. Schools projecting near the head of the vector tend to have high values of the criterion variable; schools projecting onto the tail have low values. The relative values of the multiple correlation coefficients can be used to evaluate how well different criterion variables are described by one model and how well competing models account for one criterion variable.

Chapter III

RESULTS

Spatial Models of Medical School Similarities

Figures 1 and 2 present the two dimensional models of private and public medical school similarity resulting from metric multidimensional scalings of computed similarities. Close proximity on the "map" represents a high degree of similarity with respect to twelve input variables, while large distances represent dissimilarity. For example, Yale and Chicago-Pritzker are represented as similar to one another (in the upper-left corner) and dissimilar to Mt. Sinai (lower left) and to Loma Linda (lower right). Mt. Sinai is most similar to Harvard, Harvard is most similar to Columbia. Possible interpretations of the meanings of directions and regions in the multidimensional map are addressed in the following sections.

Multiple Correlations

As described in the preceding chapter, multiple regression may be used *post hoc* to indicate the possible meanings of directions on the map. The b-coefficients and the origin define the vector; the multiple-R indicates goodness-of-fit.

Some of the vectors corresponding to the best fit (as defined in Chapter II) of several individual variables into the space are plotted in Figures 3 and 4. The multiple correlation coefficient describing the degree of fit is presented beside the variable name near the head of each vector. (The major coordinate axes do not have meaning of their own.) A multiple correlation of 1.00 would indicate perfect fit; zero would indicate no fit. The ratio of basic science graduate students to undergraduate medical students, one possible indicator of research emphasis, has a fairly high index of fit, .82 in Figure 3, .84 in Figure 4. Lines that could be drawn from "Yale" and "Chicago" perpendicular to the vector would intersect the vector near its head. This indicates that Yale and Chicago probably have the highest basic science to medical student ratios of all private schools. Loma Linda probably has the lowest values or at least one of the lower values. (The word "probably" is used because the model represents a best "fit" and not a perfect representation.) "Mt. Sinai" lies farthest out of all private schools in the direction of the vector representing the ratio of housestaff to medical students, probably indicating a relatively strong institutional emphasis on graduate medical education. In

Figure 1 Two-Dimensional Model of Similarities Between 44 Private Medical Schools With Respect to Measures of Research Emphasis and Graduate Medical Education Emphasis

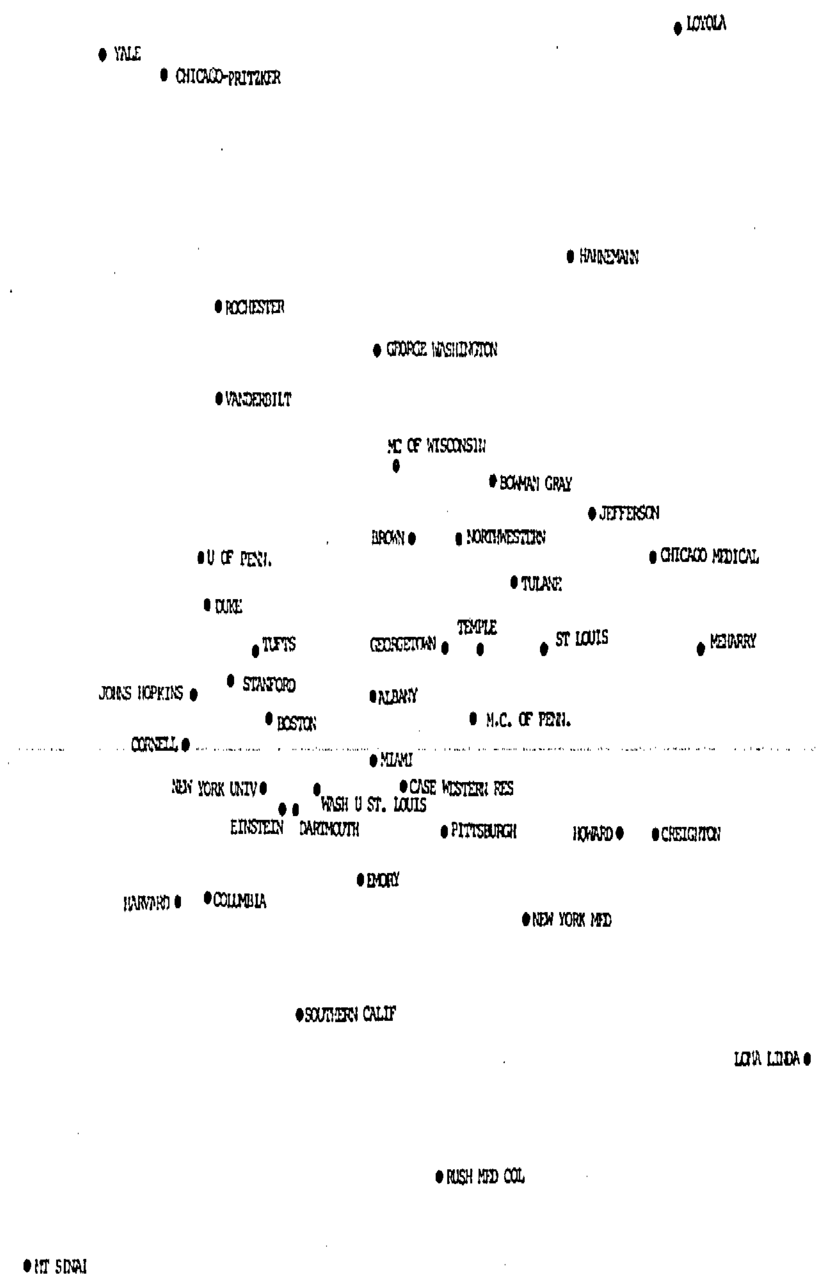
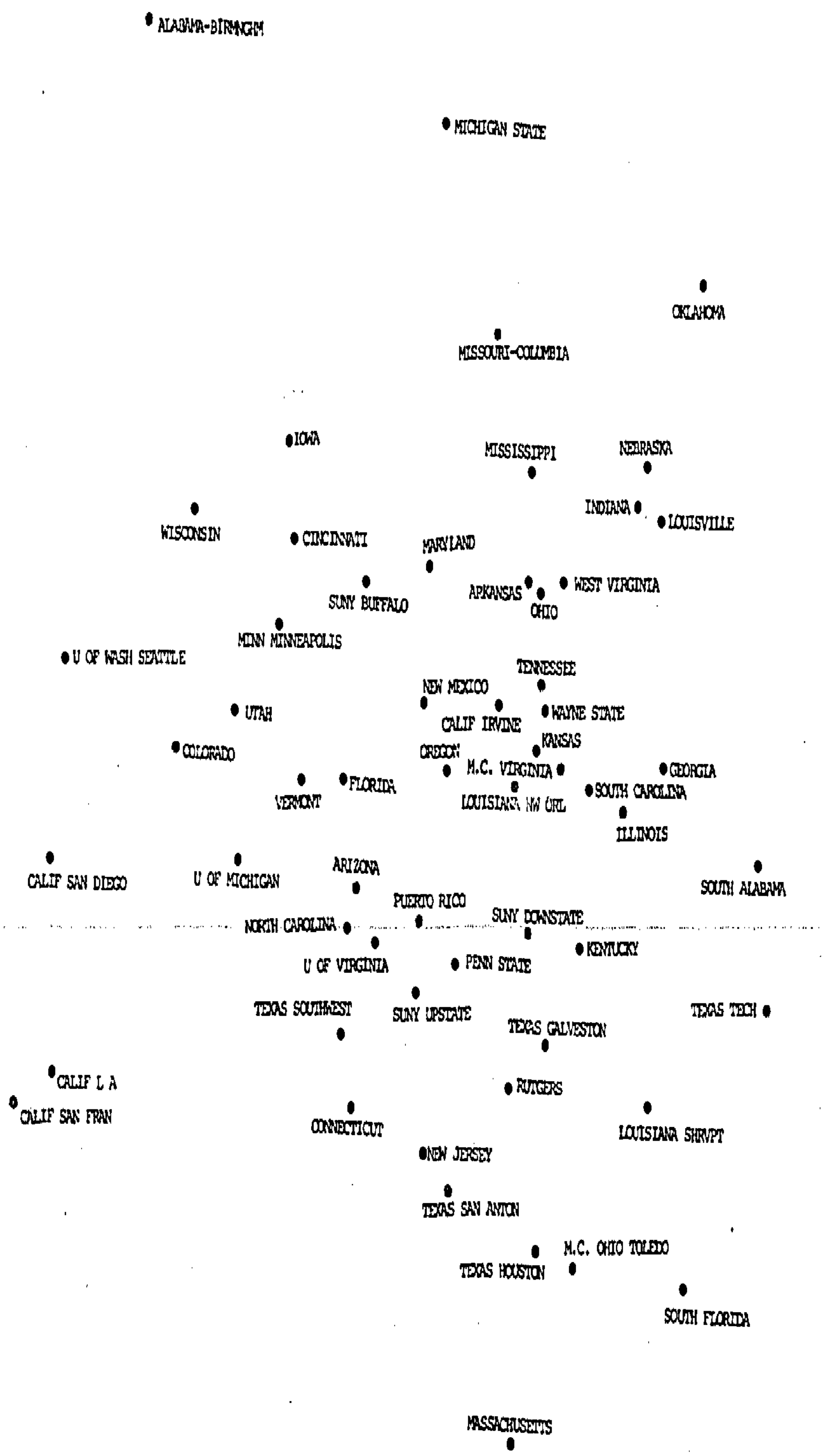
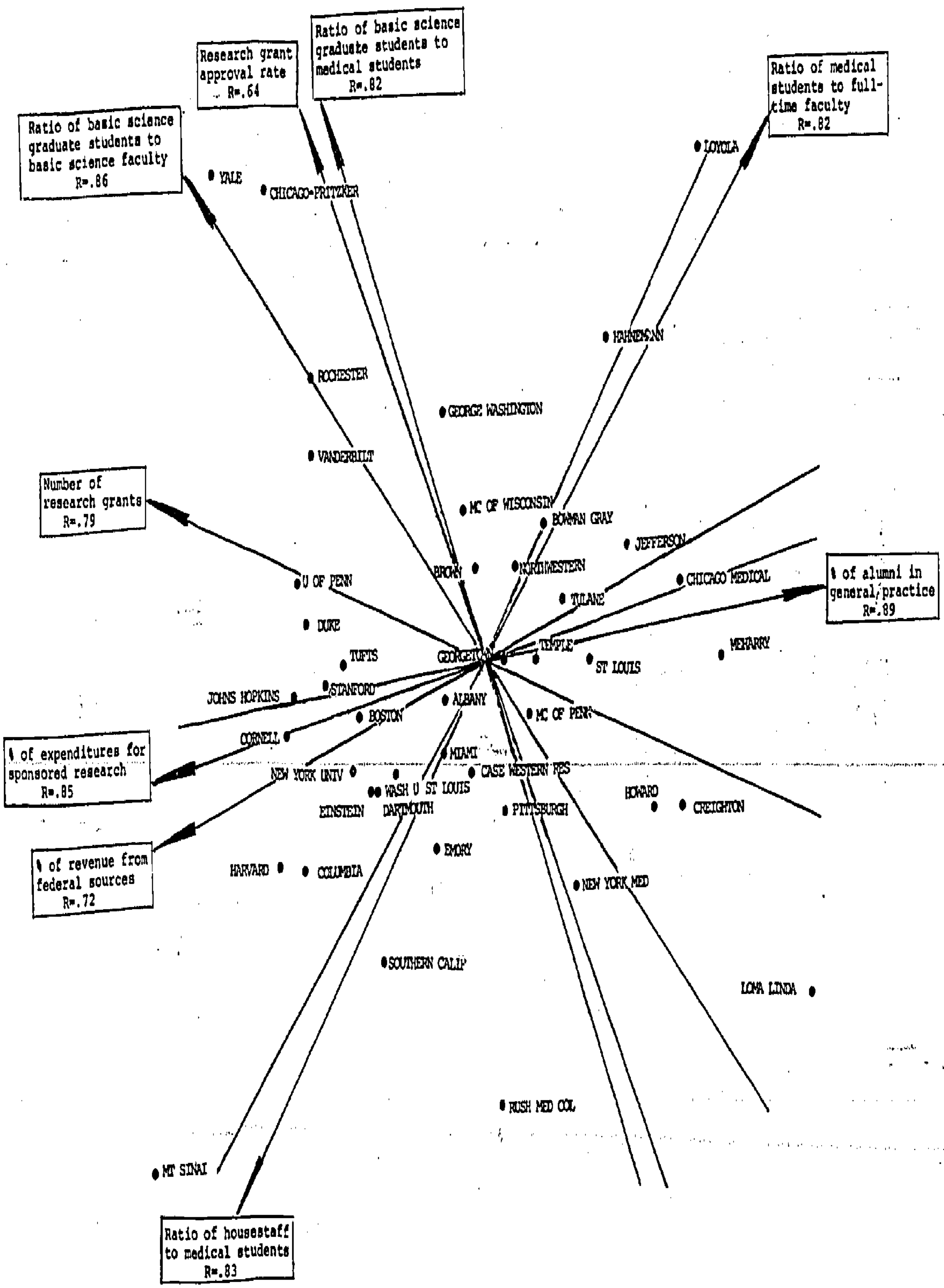


Figure 2 Two-Dimensional Model of Similarities Between 55 Public Medical Schools With Respect to Measures of Research Emphasis and Graduate Medical Education Emphasis



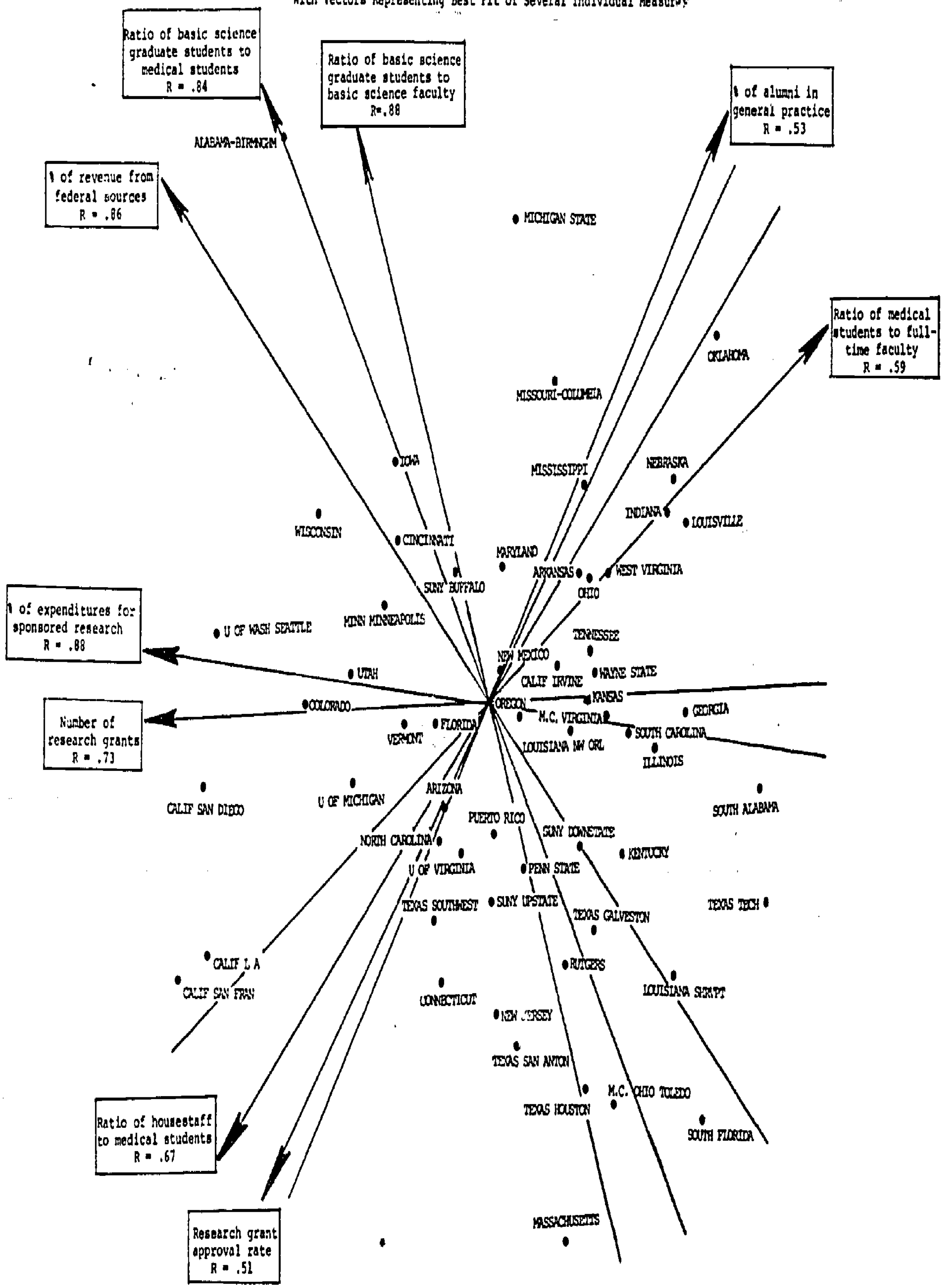
- 13 -

Figure 3 Two Dimensional Model of Similarities Between 44 Private Medical Schools With Respect to Measures of Research Emphasis and Graduate Medical Education Emphasis, With Vectors Representing Best Fit of Several Individual Measures



- 14 -

Figure 4 Two-Dimensional Model of Similarities Between 58 Public Medical Schools With Respect to Measures of Research Emphasis and Graduate Medical Education Emphasis With Vectors Representing Best Fit of Several Individual Measures



- 15 -

26

27

the model of public school similarities (Figure 4), California at San Francisco and UCLA appear to place the greatest emphasis on graduate medical education.

The multiple correlations indicating the relative goodness-of-fit of an assortment of 33 descriptive variables in each of eight models are presented in Table 2. With the exception of the last variable and to the exclusion of the "public versus private" variable, the variables listed are those used in the recent factor analytic study (Sherman, 1977). The 12 variables used in the construction of the original similarity indices for this study are highlighted in "boxes." The multiple correlation coefficients may be used to compare the public and private models, the three- and two-dimensional models, and the metric and non-metric models.

Public and Private Models Compared

Private medical school similarities appear to be somewhat more accurately modelled than are public schools. In the two-dimensional models seven multiple-R's for private schools are greater than .75. This may be compared with four such measures for public schools. In the three-dimensional models the numbers of well fitting vectors (again arbitrarily defined as $R > .75$) are 9 and 5 for private and public schools respectively.

While research-emphasis variables (percent of expenditures for sponsored research, graduate students per medical student, graduate students per basic science faculty) appear to fit well in both public and private models, graduate medical emphasis variables fit well in only the private school model. Neither metric two-dimensional model provides an exceptional fit for two proxy measures of research quality, mean priority score and rate of research grant approval. One measure of research extensiveness, number of research grants approved (not used in the construction of the similarity indices), fits moderately well in both of the two-dimensional spatial models.

It is noteworthy that school variation in the "percent of revenue from federal sources" is more accurately represented in the <u>public</u> school model than in the private school model ($\bar{R} = .86$ vs. .72). This is probably true because, in the case of public schools, federal revenue is mostly research revenue and therefore adequately modeled by the "research emphasis" component of the space. Private schools' receipt of federal monies may follow slightly different patterns.

Table 2

Multiple Correlation Coefficients
Indicating Goodness-of-Fit of 33 Vectors in Each of 8 Spaces
(Decimal Points Have Been Omitted)

Variable	3 Dimensions: Public Metric	3 Dimensions: Public Non-Met	3 Dimensions: Private Metric	3 Dimensions: Private Non-Met	2 Dimensions: Public Metric	2 Dimensions: Public Non-Met	2 Dimensions: Private Metric	2 Dimensions: Private Non-Met
1. VAR388 AV SALARY - SFT ASSOC PROF BASIC SCIENCE	66	63	71	73	64	55	65	68
2. STC043 RAT: HOUSESTAFF TO UNDERGRAD MD-STUD	73	71	83	83	67	77	83	79
3. INC058 RAT: MD STUDENTS TO FT FAC	59	56	82	84	59	53	82	81
4. STC105 % LIVING MD-ALUMNI IN GENERAL PRACTICE	66	64	91	92	53	25	89	90
5. FAC001 % PT & FT SAL FAC WITH MD	76	75	24	25	41	54	23	28
6. VAR016 # MD-STUDENTS	38	33	27	28	34	30	24	22
7. INC048 LOG AGE OF MEDICAL SCHOOL	55	51	29	29	50	46	28	20
8. STC112 % LIVING MD ALUM BOARD CERTIFIED	30	22	49	48	24	21	49	45
9. VAR394 1975-76 RESIDENT MD-STUDENT TUITION	24	29	42	44	21	26	39	42
10. STC029 % IN-STATE 1ST-YR MD-STUD	43	41	20	19	43	40	18	14
11. STC084 RAT: APPLICANTS PER 1ST-YR MD-STUD	41	40	21	25	40	44	19	13
12. INC007 % REV FROM FED SOURCES & RCOV IND COSTS	88	84	72	70	86	83	72	68
13. INC012 % REV FROM ALL GIFTS	29	25	24	24	27	23	20	17
14. STC082 % UNDERREP MINORITY 1ST-YR MD-STUD	33	35	34	32	26	37	28	32
15. FAC004 % PT & FT SAL FAC FROM ETHNIC MINORITIES	13	27	40	40	8	18	35	38
16. STC008 % NON US-CANADIAN 1ST-YR MD-STUD	35	34	32	29	33	29	23	27
17. VAR093 1ST-YR MD-STUD: MEAN MCAT SCIENCE SCORE	60	61	70	71	59	50	70	70
18. INC046 NIH-NIMH R01 $ AWARD AS % OF $ APP SBMT	57	58	62	63	42	27	50	57
19. VAR352 IMPAC: MEAN STD P-SCR - R01 APP	69	71	82	78	67	59	57	56
20. INC045 IRG APPROVAL RATE OF NIH R01 COMP APPS	72	80	88	81	51	33	69	73
21. STC003 % FEMALE MD STUDENTS	36	32	27	27	29	25	21	17
22. VAR273 REL ELECTIVES: ALCOHOLISM	18	18	41	45	16	20	40	43
23. CRC002 # OF RELATED ELECTIVES OFFERED	24	31	53	56	22	21	52	51
24. FAC019 RAT: VOL FAC TO FT FAC	19	20	41	47	18	26	41	48
25. INC003 DRG FED SPON RES CON$ % CHG 67-9 TO 72-4	38	38	42	40	35	42	21	25
26. STC114 PROJTD ANNL % 1ST-YR ENROLL CHG: 1947-79	46	47	20	23	44	44	15	8
27. VAR384 DRG GRANTS - # R01 APPS APPROVED	73	71	80	76	73	68	79	76
28. INC026 % EXPD FOR ADMIN & GENL EXPENSE	68	69	72	71	60	63	28	47
29. INC017 % TOTAL EXPD FOR SPON RESEARCH	90	86	87	87	88	84	85	84
30. STC045 RAT: BMS GRAD-STUD TO UNDERGRAD MD-STUD	94	90	90	87	84	85	82	77
31. INC004 ADJUSTED TOTAL REVENUE	66	64	62	59	66	62	61	59
32. STC013 % 1ST-YR MD-STUD: PRE-MED GPA 3.6-4.0	45	47	45	40	44	47	38	31
33. INC061 RAT: BMS GRAD STUD TO BAS SCI FT FAC	93	89	91	92	88	85	86	71

*Variables in "boxes" were used in derivation of similarity index.

- 17 -

The configurations of vectors that fit well in Figures 3 and 4 (ignoring momentarily "research grant approval rate" and others with R's less than .65) appear to be highly similar to one another. Vectors representing the ratios of graduate students per medical student and housestaff per medical student are approximately perpendicular, and the two fiscal percentage variables lie in between. "Number of research grants" is most nearly co-linear with "percent of expenditures for sponsored research".

Vectors with smaller multiple-R's are to be interpreted with caution, but they do show some interesting tentative relationships. In the private school model (Figure 3) the "percent of alumni in general practice" vector fits well (R - .89) and is nearly co-linear with (and in opposition to) "percent of expenditures for sponsored research". In the public school model (Figure 4) neither "% GP alumni" nor "research grant approval rate" fits well (R = .53 and .51 respectively) but they appear to be linear opposites and are obliquely related to "sponsored research expenditures." It may be that relationships that hold between private schools do not hold between public schools. On the other hand, it may be that public medical schools are more complex and less readily portrayed by a simple two-dimensional model than are private medical schools.

At the level of two-dimensions, public school variation in "percent of expenditures for general administration" is modelled to a better degree than the same variation for private schools. When a third dimension is allowed, information about private school administrative differences is added to the model; the public school model is also improved.

Three-Dimensional and Two-Dimensional Models Compared

A three-dimensional model necessarily provides a greater likelihood of accurate representation of twelve-dimensional similarities data than does a two-dimensional model. A three-dimensional model is also more difficult to depict graphically and to visualize and, though more accurate, possibly less useful. The multiple-R's in Table 2 for the three-dimensional models are necessarily higher than those for the two-dimensional models derived from the same data.

The private model is not greatly improved by the addition of a third dimension. The third dimension allows for high multiple-R's for the two proxy measures of research quality: mean priority score and rate of research grant approval. As described above, administrative fiscal information is also added with a third dimension.

The public school similarity model is improved by the use of a third-dimension for the representation, not only of research grant approval ratio, but of several graduate medical program variables. The "percent of part-time and full-time faculty with MD degrees" vector is fairly well portrayed <u>only</u> in the three-dimensional public school model.

Metric and Non-Metric Scaling Models Compared

"Maps" of the non-metric multidimensional scaling models of public and private medical school similarity are not presented in this report because they are nearly identical to the metric models. (The canonical correlations between the two-dimensional metric and non-metric coordinates were .98 and .87; for three dimensions, .99, .98, and .95.) The multiple-R's in Table 2 are of comparable magnitudes and show no patterns of difference.

Non-metric scaling allows for a relaxation of the assumption that the similarities between pairs of schools are measured on a ratio scale of accuracy. Since the Euclidian distance formula was used to <u>compute</u> the similariites, the assumption is easily made.

If, however, the computed similarities are viewed as rough indicators, not strict measures, of the general constructs of research emphasis and graduate medical education emphasis, the non-metric models may be better than the metric models in ways not reflected by multiple regression methods with existing variables as criterion variables. A proper comparison of the metric and non-metric models must be made by a person with some familiarity with all medical schools plotted in the respective models.

In the non-metric models (not shown), compared with the metric models, the schools plotted on the "outside" are further out from the densely clustered schools near the center. Few schools are located in very different regions of the spaces. "California at Irvine" is located midway between

"Massachusetts" and "UCLA" on the outer fringe of the non-metric model. Puerto Rico, too, is located further out in the direction of the "housestaff per student" vector.

Comparison with Cluster Analysis of Medical Schools

Cluster analysis refers to the grouping of objects (here, medical schools) that are similar to one another according to a series of subjective and objective criteria. The resulting groups constitute a model of similarity, different in form from a multidimensional scaling model (see Chapter I).

Based on six composite institutional measures (factor scores) selected from eight principal components derived by Sherman (1977), McShane performed a cluster analysis of 110 U.S. medical schools. Details of the data and the methods used are presented elsewhere (McShane, 1977b). The results in the form of eight groups of school names accompanied by mean descriptive profiles are presented in Figure 5. Eight symbols have been added to column 3 to designate the eight groups.

The eight symbols have been used in Figures 6 and 7 to plot school locations on the two-dimensional models of medical school similarity derived by metric multidimensional scaling. The combined models presented in Figures 6 and 7 allow for an enhanced examination of medical school similarities. Locations on the "map" describe relative similarity with respect to two basic characteristics: graduate medical program emphasis and research emphasis. Cluster membership, designated by the plotted symbols, reflects similarity with respect to institutional size, public versus private control, stage of development, and research funding success as well as research and graduate program emphasis.

As may be seen in Figures 6 and 7, schools in the same region of the map tend to be members of the same cluster. Overlap is most notable in the public school model. Some overlap between models is also apparent. Vermont, a public school, is a member of a cluster that consists mostly of private schools (represented by solid triangles). Jefferson and Temple, two private schools, are associated (in similarity) with a group of mostly public schools (both receive substantial funding from the State of Pennsylvania). Large schools with heavy graduate program emphasis (solid stars) appear in both public and private spatial models.

Figure 5

Cluster Membership and Profiles of Cluster Centroids on Six Factor Scores (from McShane, 1977b)

	MEMBERSHIP	SYMBOL
CLUSTER 1	Maryland, Oregon, Louisiana NW Orl, M.C. Of Virginia, Tennessee, Ohio, Georgia, Arkansas, Mississippi, So. Carolina, Kentucky, Nebraska, Rutgers, So. Alabama, So. Dakota, Oklahoma, Louisville	●
CLUSTER 2	Temple, Wayne State, SUNY-Buffalo, SUNY-Downstate, Texas-Galveston, Indiana, Illinois, Jefferson	□
CLUSTER 3	Utah, Florida, Kansas, Colorado, North Carolina, Wisconsin, Iowa, New Mexico, Puerto Rico, Connecticut, U Of Virginia Missouri-Columb Alabama-Birminghm, Arizona, West Virginia U Of Wash Seattle	◆
CLUSTER 4	Pittsburgh, New York Univ. Miami, Einstein, Columbia, SUNY-Upstate, Texas-Southwest, Calif-LA, U Of Michigan, New York Med, New Jersey Harvard, Calif-San Fran, Minn-Minneapolis	★

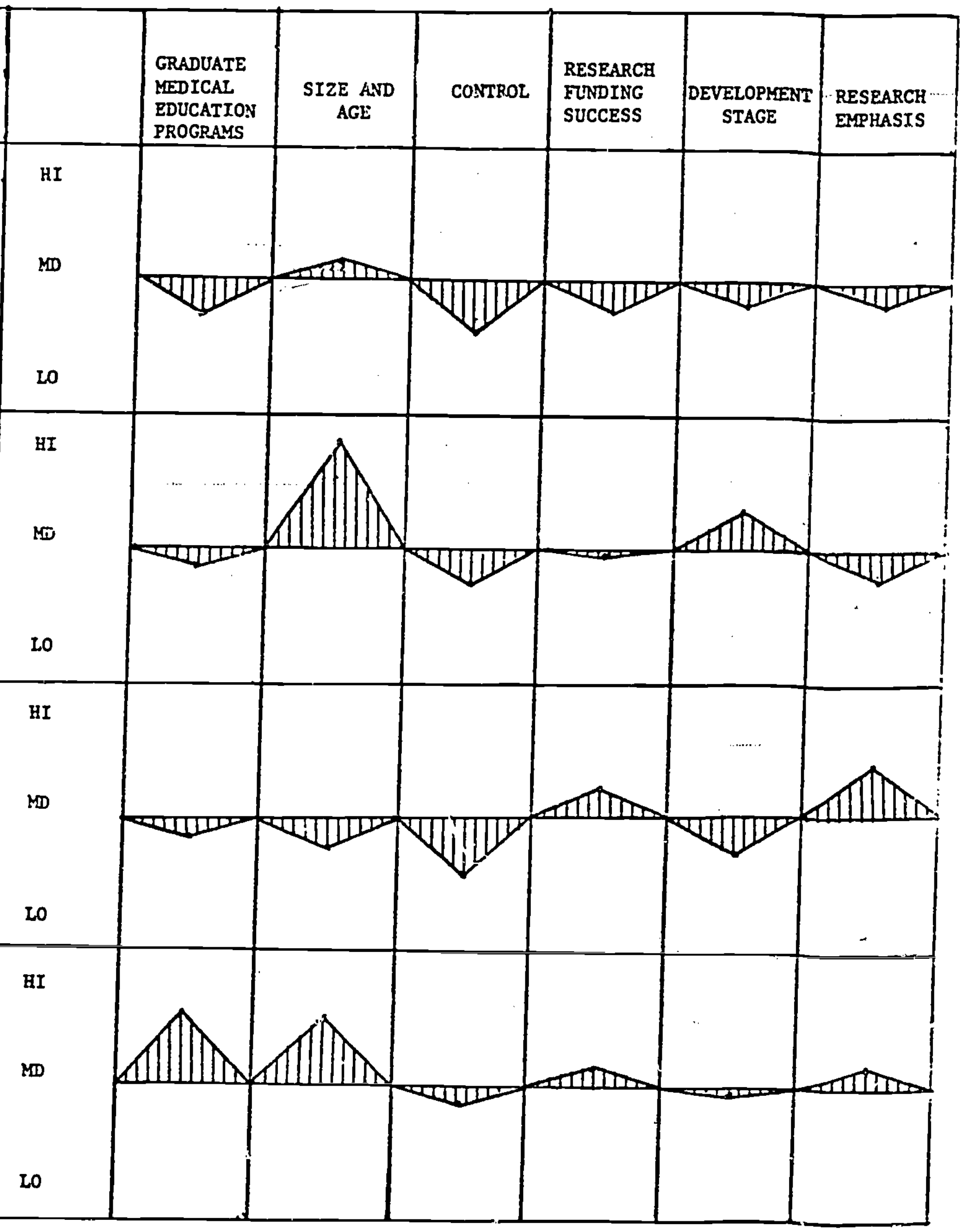


Figure 5
(Continued)

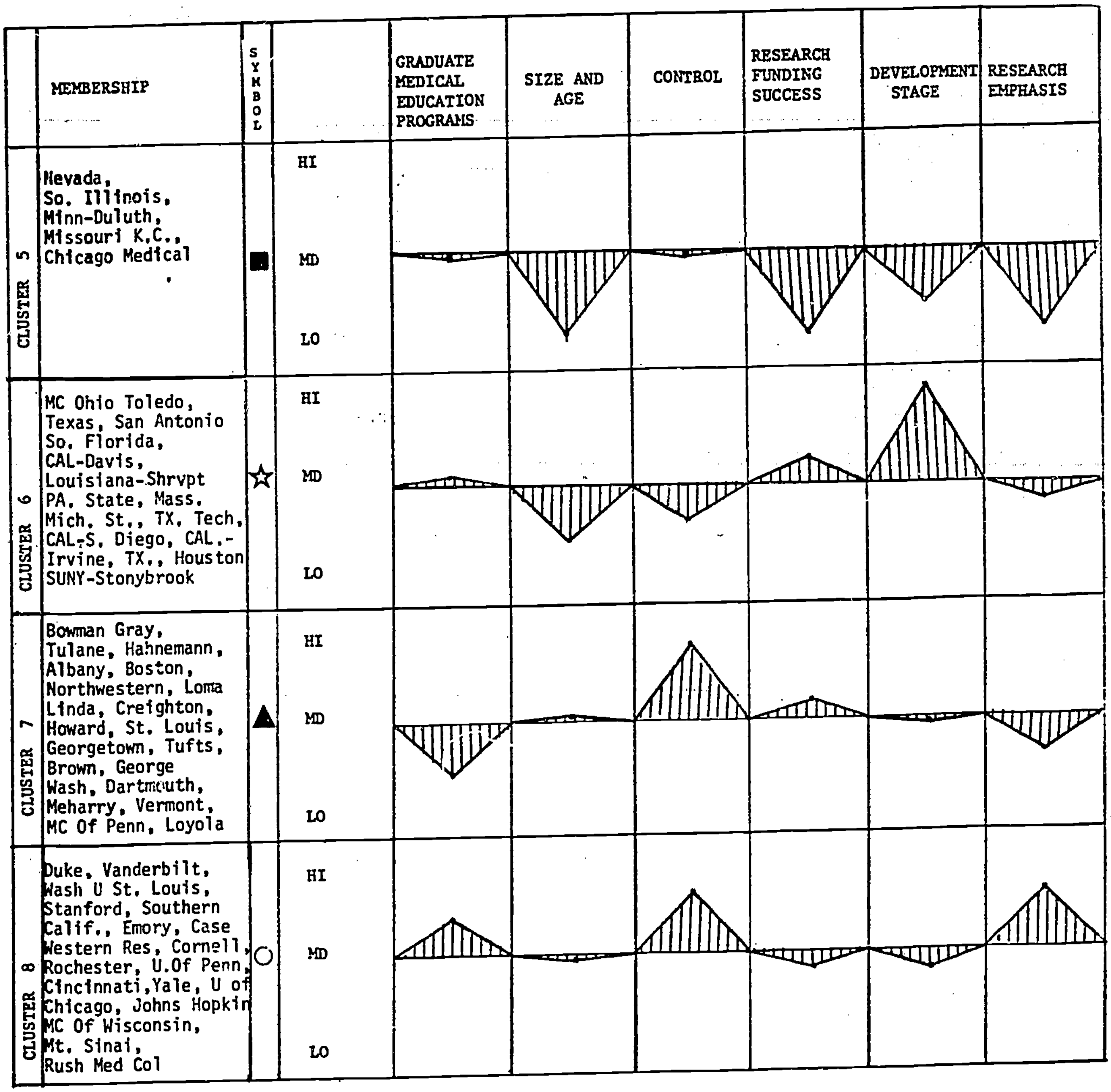
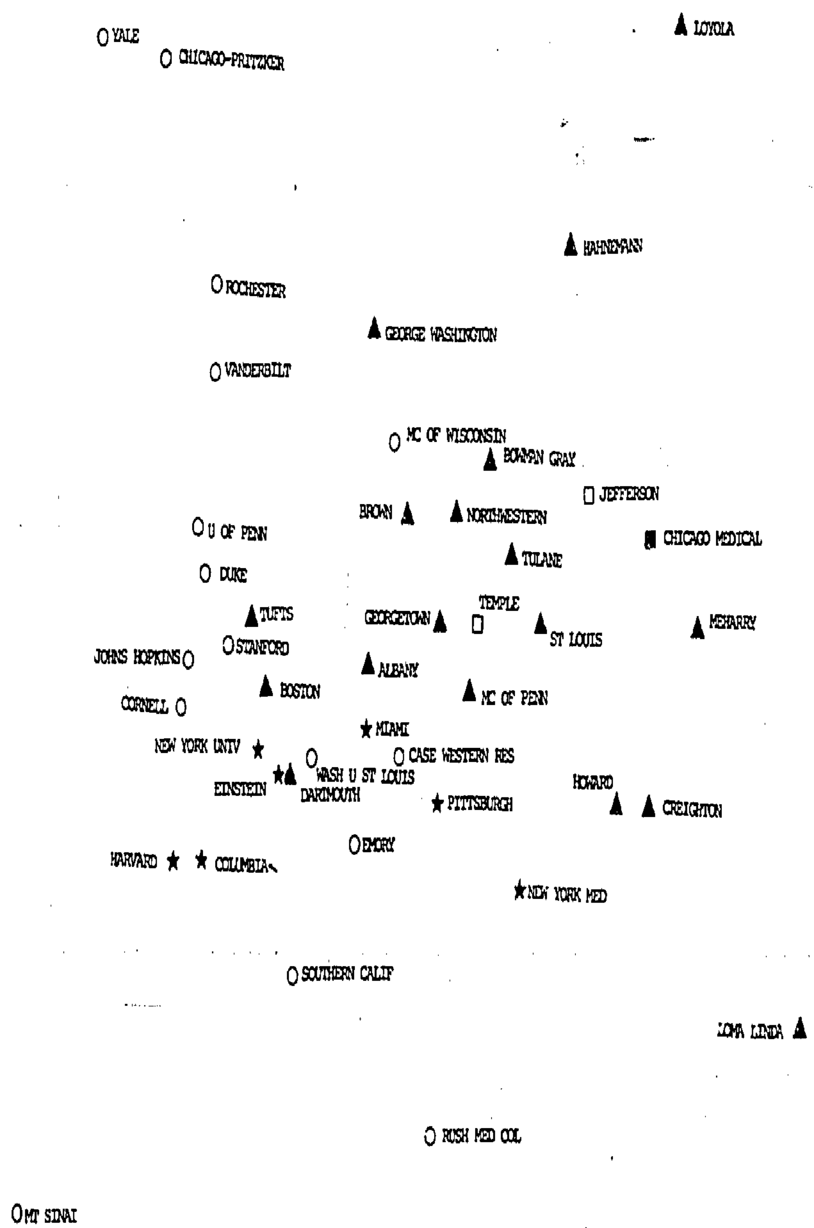


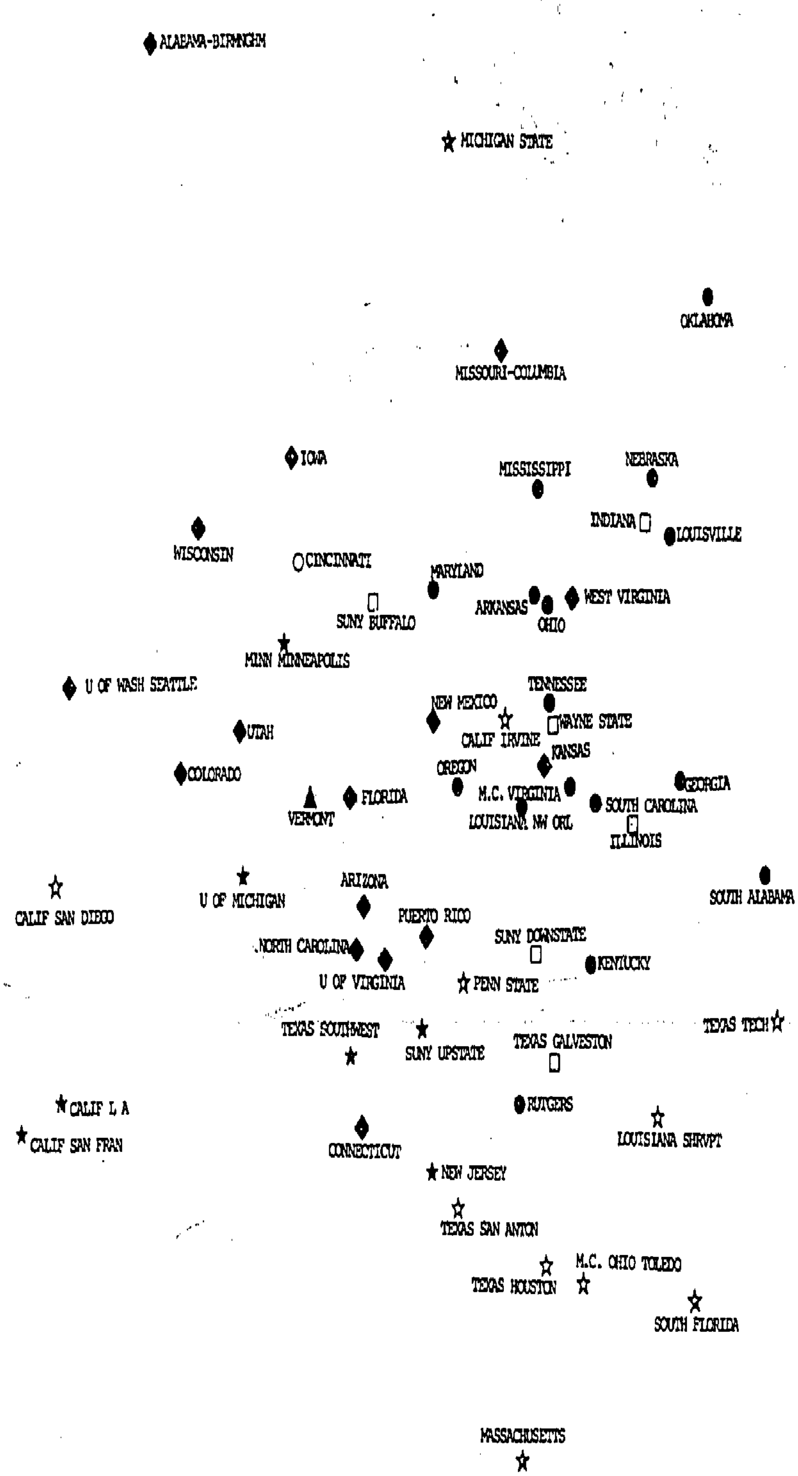
Figure 6

Two-Dimensional Similarity Model of 44 Private Medical Schools Plotted to Indicate Eight Cluster Memberships



- 23 -

Figure 7 Two-Dimensional Similarity Model of 58 Public Medical Schools Plotted to Indicate Eight Cluster Memberships



The private school scaling model discriminates best between schools having both graduate and research emphases (cluster 8, represented by circles) and schools having neither emphasis (cluster 7, solid triangles).

The public school scaling model discriminates best between three groups: developing schools (cluster 6, vacant stars), schools with both moderate research emphasis and research funding success (cluster 3, diamonds), and schools with a relative lack of research emphasis and funding success (cluster 1, dots). Exceptions from perfect discrimination are readily recognizable. California at San Diego appears to be a developing school (plotted as a vacant star) with characteristics already similar to large schools with heavy emphases on graduate medical education and moderate emphasis on research. Michigan State and California at Irvine are also excepted, although in different ways.

Schools with very large enrollments such as Indiana and Illinois are distinguished by being in a cluster of their own (cluster 2, boxes).

The lack of fit of vectors in the public school model, described above, may be explained in part through the comparison with the cluster model. If schools having high, medium and low measured values of a certain variable do not fall in a line, but rather in <u>regions</u> of the space, projections onto a straight line would not be expected to show a high degree of correspondence with the measure. The public school model may therefore be best described in terms of regions rather than directions. The scaling and clustering models of similarity seem to complement one another.

Chapter IV

SUMMARY AND CONCLUSION

Multidimensional scaling methods were used to derive interpretable models of medical school similarity with respect to research and graduate medical education intensiveness. Two- and three-dimensional models of both public and private medical schools using both metric and non-metric scaling procedures were derived. Two-dimensional "metric" models of public and private schools were presented in the form of spatial "maps". The relative merits of several models were discussed.

The similarities of private medical schools were more adequately represented by a two-dimensional model than were the similarities of public schools. More directional vectors, representing unidimensional school variation on single measures, were found to fit well in the private model than in the public model. The relative directions of the vectors that did fit in both models were found to be highly similar, allowing for rotation and symmetric reflection.

Using the goodness-of-fit of single vectors as an evaluative criterion, the non-metric scaling models did not appear to be appreciably different from the metric scaling models. Visual comparisons did not expose major differences, only the re-location of a few schools on the "maps". The high degree of similarity of the metric and non-metric models was largely due to the use of the Euclidian distance function in the computation of profile similarity indices. Other similarity indices may be found in future studies to lead to better models of medical school similarity.

While two dimensions appeared to suffice in representing medical school differences in research and graduate program emphases, a third dimension allowed for institutional variation in proxy measures of research quality and in measures of administrative costs.

The imposition of a cluster analysis model of medical school similarities with respect to six factors onto the multidimensional scaling model for two factors seemed to enhance the interpretation of <u>both</u> models. On the basis of cluster analysis, private schools seemed to be categorizable into those that are relatively intensive on both research and graduate medical education, those that are not intensive on either, and some that, along with some public schools, are both extensive and intensive on graduate medical programs. These groups are readily apparent in the scaling model, but gradations of difference within groups are also apparent. The public schools showed similar separability along continuous dimensions of difference.

The models of similarity derived and compared in the present study are simplifications of the information contained in data provided by the medical schools and the NIH's records of grant applications. The validity and usefulness of the models must now be assessed by individuals with an informed familiarity with many schools. Any problems observed in the current models may guide improvements in the models and in the overall understanding of medical education institutions.

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