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ABSTRACT

This study investigates the effects of content sequence on student learning. The treatments, a spatial and conceptual instructional sequence each consisting of identical content elements, were administered to students in a two-year college Botany course. Hypotheses tested were that sequence would have an effect on student perceptions of the lesson, that the sequencing principle would be learned, and that students would exhibit differential cognitive structures corresponding to the sequences. It was also hypothesized that sequence would not affect recall of the material. The results supported these hypotheses as the two sequences of content resulted in significantly different outcomes. (Author)

Session # 10.05

# The Effect of Content Sequence on Student Learning



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What one chooses to teach and the emphasis one gives to this content are considered by some to be the two most significant variables affecting the educative process (see Walker and Schaffarzick, 1974). Other variables, such as instructional method and administrative arrangements, have shown to be of lesser significance (Stephens, 1967; Jamison, Suppes and Wells, 1974). But what one teaches and the emphasis one gives it is not necessarily communicated explicitly. Consider a stipulated definition of curriculum as "a structured series of intended learning outcomes" (Johnson, 1967). This definition suggests that when one teaches a particular set of content elements (i.e., particular concepts, propositions, affects, cognitive competencies, and perceptual-psychomotor skills), he not only teaches the particular content elements, but also relationships among the elements (i.e., the content structure). The structure of content taught presumably affects, among other things, the cognitive structure of the learners.

Paper presented at the 1976 Annual Meeting of the American Educational Research Association, San Francisco.

Many researchers in education, cognitive psychology, and reading have been developing techniques and theories for describing the structure of prose material and the structure of concepts in a person's mind. Most of this research has been "focused on the structure of sentences in isolation with only peripheral attention to larger stretches of speech" (Chafe, 1972). Crothers (1972) asserts that "the proper unit of analysis" is "overall knowledge structure and not a set of independent sentences." Rothkopf (1972) seems to be agreeing when he contends that "...certain formal characteristics of language that have been shown by experiment to affect verbal learning may not be very powerful in determining what is learned from substantial quantities of written discourse."

The work of Richard Shavelson is particularly significant for curriculum research in that his research has been focused on the structure of instructional units rather than on the structure of sentences.

Shavelson and his colleagues have conducted a number of studies concerned with the representation and assessment of content and cognitive structure (Shavelson, 1971, 1974; Shavelson and Stanton, 1975; Geeslin and Shavelson, 1975; Geeslin, 1973). The procedure for analyzing content structure developed by Shavelson (1971) consists in identifying key concepts in text, parsing every text sentence containing two or more key concepts using a surface structure grammar, converting these grammatical tree diagrams to directed graphs (i.e., "digraphs") using a set of rules for mapping a grammatical relation into directed lines, combining all the individual digraphs into a super digraph, and translating the super-digraph into a distance matrix which can then be visually represented as a multidimensional scaling solution.

Shavelson employs word association, card sorting or clustering, and graph building as measures of cognitive structure. These measures yield matrices of similarity or dissimilarity among key concepts which can then be visually represented as a multidimensional scaling solution. Shavelson and Stanton (1975) used these three measures to investigate the construct validity of cognitive structure and found that the representations resulting from these measures were convergent.

Shavelson (1971) found that the cognitive structure of subjects learning physics from a particular text comes to resemble the content structure of that text. Evidence for this claim is found by comparing subjects who have used the text with a control group that did not study the topic. Further evidence is that the cognitive structure of the "instructed" group shows increasing similarity to the text's content structure over testing occasions.

However intriguing Shavelson's research appears to be, he has left several methodological problems unresolved. These problems center around his use of grammatical analysis of text structure and his experimental design employing only "instructed" and "non-instructed" groups.

Two deficiencies in Shavelson's research stem from his approach to the representation and assessment of content structure. First, his use of a surface structure grammar to parse sentences attends only to syntax rather than to deep or semantic structure. Second, content structure analysis was confined to sentence sized units. This approach overlooks relationships among key concepts not expressed in a single sentence and, further, raises suspicions on any claims that the content structure thus derived is semantically meaningful.

Shavelson's experimental design also raises questions regarding the adequacy of his techniques for representing content structure. By employing only "instructed" and "non-instructed" treatment groups, the discriminatory power of his techniques was not tested, since only gross discriminations were required by the techniques. The fact that the techniques did discriminate between the "instructed" and the "non-instructed" groups, both in terms of content structures and resulting cognitive structures, does not conclusively support the claim that a person's cognitive structure approximates the content structure of the instructional materials used to instruct him. It may be the case that the resulting cognitive structure is the only one possible after instruction in the discipline, regardless of the content structure of the materials. What seems to be required is a study comparing the effects of at least two different content structures on a person's cognitive structure. Such a study should demonstrate that the techniques for representing content structure do, in fact, discriminate between the two content structures. Further, the study should show that the two content structures result in predictably different cognitive structures.

In light of the above deficiencies, the present research study:

1) Employs techniques for representing content structure of instructional materials focusing on semantic structure, and these techniques are compared with those of Shavelson.

2) Employs techniques for representing content structure of instructional materials focusing on units larger than sentences. These techniques are also compared with those of Shavelson.

3) Employs three experimental groups. Two groups are taught the same content elements but each group receives a different content structure. A third comparable baseline group receives no instruction in the subject matter. These three groups are compared with respect to their resulting cognitive structures.

## METHOD

### Subjects

The two instructed groups were constituted from a pool of 116 first and second year students enrolled in a botany course at Corning Community College. All students were non-science majors taking this course to fulfill their science requirement for an Associates Degree.

The baseline group was comprised of 20 students from Cayuga County Community College. They were also first and second year non-science majors.

The groups from the two colleges were considered adequately similar to be compared, since a) the two communities are of similar size, b) they are both located in central New York, c) all students had had no biology beyond high school, and d) all students were enrolled in similar programs at the colleges.

Instructional Materials

The material to be covered in the "Growth and Development" unit was specified by the course instructor. Seventeen concepts contained in this material were identified as key concepts of the unit. They were seed, root, stem, structure, tissues, functions, growth, cell, specialization, germinate, monocot/dicot, meristematic region, elongation region, maturation region, cell division, cell elongation, and cell maturation.

Using the instructor's specifications as to what students should learn and the seventeen key concepts as input, two versions of "Growth and Development" were written. One version, termed World-related (Posner and Strike, in press), sequences the course content on the basis of spatial and temporal characteristics of higher plants. This version begins with the seed, then discusses the root, and lastly the stem. Temporally, a plant develops from a seed. Upon germination the first plant structure emerging from a seed is the root followed by the stem. In each major s[illegible]ion of this version (i.e., seed, root, stem) the concepts of structure, tissues, function, and growth are developed for and organized around each plant part.

The other version of "Growth and Development," termed Concept-related (Posner, Strike, 1976, in press), sequences the course content on the basis of conceptual properties of that content. This version begins with plant structures and then discusses tissues, functions, and growth in that order. These are the four major concepts under which the rest of the unit's content can be organized. In each major section of this version (i.e., structures, tissues, functions, growth) seeds, roots, and stems are discussed in relation to the particular organizing concept. The two versions differ only in their sequencing and grouping of content. The actual content found in both is identical.

These two versions (i.e., World- and Concept-related) are presented to students in the form of scripts and corresponding audio-tape. Each script is accompanied by a study guide. The study guides for each version are identical in terms of content, diagrams, and questions. They differ only in sequence. The demonstrations and student experiments accompanying the scripts and study guides are also identical. The order in which a student would experience the demonstrations depends upon which script and tape version the student is following. However, all students experience all demonstrations.

## Instrumentation and Techniques

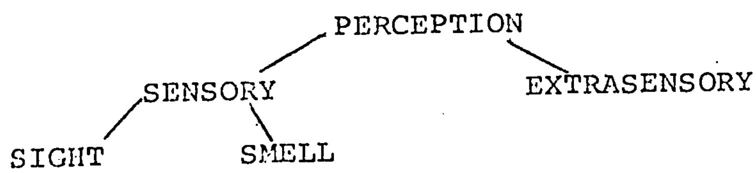
All of the analyses (except the Recall Quiz) result in a 17x17 matrix (corresponding to the 17 key concepts) expressing the similarity or dissimilarity among the key concepts. All matrices are scaled using Version V of Kruskal's Multidimensional Scaling. This section explains briefly the instruments and techniques used to generate the data that comprised each matrix.

Digraph Analysis of Content Structure is a procedure developed by Shavelson (1971) and is based on a grammatical analysis of text. In brief, the procedure involves the following steps:

1. Identifying every sentence in the text that contains two or more key concepts.
2. Diagramming each identified sentence using a parsing grammar like that suggested by Warriner and Griffeth (1957).
3. Converting each sentence diagram into a digraph using a set of rules developed by Shavelson.
4. Combining the individual digraphs into a super digraph by using digraph theory (Harary, et.al., 1965).
5. Transforming the super digraph into adjacency matrices, then into a distance matrix, and finally into a symmetric distance matrix.

Each distance in the matrix represents how closely two concepts in the text are related (in a grammatical or syntactic sense).

Judges' Graph Analysis of Content Structure is a technique developed for the present study in an attempt to represent the text's content structure on the basis of semantic rather than syntactical relations among key concepts in the text. Five judges analyzed the Concept-related script and five judges analyzed the World-related script. Following a set of rules, each judge summarized the script into a much shorter piece of prose. Key concepts were identified and the summary focused on meaningfully relating the key concepts as expressed in the script. Using the summary, each judge constructed a graph showing the relationships among the concepts expressed in the summary. A set of rules were also developed for this procedure. These rules were quite open-ended, emphasizing the construction of a graph which reflects the meaning of the text. Each graph was then converted to a 17x17 distance matrix. This was accomplished by finding the shortest distance between all pairs of key concepts on a graph. For example, assume the following graph represents relationships among key concepts:




This graph would result in the following distance matrix:

| | PERCEPTION | SENSORY | EXTRASENSORY | SIGHT | SMELL |
|---|---|---|---|---|---|
| PERCEPTION | 0 | 1 | 1 | 2 | 2 |
| SENSORY | 1 | 0 | 2 | 1 | 1 |
| EXTRASENSORY | 1 | 2 | 0 | 3 | 3 |
| SIGHT | 2 | 1 | 3 | 0 | 2 |
| SMELL | 2 | 1 | 3 | 2 | 0 |

A mean distance matrix was computed for each version of the script from the five judges' matrices.

Recall Quiz was a 20 item, multiple-choice type instrument designed to measure recall of the unit's content. From a 30 item pool, four forms of the test were constructed. A one factor ANOVA on these four forms was performed after their use. The lack of a significant F is taken as evidence for the equivalence of the forms. Intraclass reliability was computed for each form[1] with the following results:

Table 1

Reliability of Recall Quiz

| | |
|---|---|
| Form A | .74 |
| Form B | .72 |
| Form C | .76 |
| Form D | .74 |

World Association Test consisted of a page of instructions and seventeen pages for responses. At the top of each response page was one of the unit's seventeen key concepts which serve as the stimulus words. Four random orderings of stimulus words were used to construct the four forms of the Word Association Test. Subjects responded to a stimulus word with all the "biological" associations they could think of in one minute. Each test was then analyzed by computing the relatedness coefficient (Garskoff and Houston, 1963) for each pair of associations. A matrix of mean relatedness coefficients was computed for the Concept-related, World-related, and Baseline groups.

Clustering Test consisted of a page of instructions and an accompanying envelope which contained seventeen cards and paper

[1]The computational formula used is one developed by Kuder and Richardson and presented by Stanley (Thorndike, 1971).

clips. On each card was a key concept and each set of cards was shuffled before being put into the envelope. Subjects were asked to sort the cards into any number of clusters they wished. Each cluster was to be comprised of concepts judged similar. A 17x17 matrix was formed for the Concept- and World-related groups. Each cell entry represented the proportion of times two concepts were clustered together (based on the number of subjects in that group).

Graphing Test consisted of an instruction page, a blank page, and an envelope containing seventeen adhesive labels each with a key concept written on it. Subjects were asked to arrange the labels on the blank page until they arrived at the best representation of how the concepts were related. They were then instructed to remove the label backing and affix it to the paper. These resulting graphs were converted to matrices in the same manner as the Judges' Graph Analysis of content structure.

## Design

The Corning Community College botany course is audio-tutorial. A large lab is set up containing tape recordings or the instructional scripts, the corresponding tape script, and demonstration areas around the lab. Students spend as much or as little time as they wish learning the unit and working through their study guide. Each student is assigned one class hour on either Monday, Tuesday, Wednesday, or Thursday. This hour is typically used to review the previous week's unit and then to take a quiz. On Friday, two sessions are scheduled and students attend one of them.

The week preceeding the "Growth and Development" unit students were assigned to one of the two treatment conditions according to the section in which they were enrolled. By chance drawing the third Wednesday session was designated World-related and the other sessions were assigned to provide balance over the week. Students received either an A or B (Concept- or World-related) study guide and were told to use a tape and/or script that corresponded to the treatment. Students were told that the study was designed to improve course materials and neither group would have a learning advantage. Students were also told that only the appropriate tape/script would correspond to their study guide.

At the hourly meetings during the following week the Recall Quiz was administered to students. During the first hour of the Friday session, students responded to the Word Association (n=56) and Graphing Tests (n=56). Students attending the second meeting responded to the Word Association (n=60) and Cluster Test (n=60). The breakdown according to treatment is as follows:

| | Number of Students Taking Tests | |
|---|---|---|
| | Concept-related Group | World-related Group |
| Word Association Test | 52 | 64 |
| Clustering Test | 29 | 31 |
| Graphing Test | 23 | 33 |

Equivalence of the two treatment groups was considered by examining high school grades and mean quiz score in the course up to the date of the study. The mean high school grade for the World-related group and the Concept-related group was 78.49 and 78.93, respectively; the difference between these means is not significant ($p < .01$).

The groups' mean quiz score in the course was 79.47 and 81.01 respectively; this difference, too, is not significant ($p < .01$). This data suggests that the two groups were equivalent on the two dimensions considered.

The baseline group (n=20) at Cayuga County Community College responded to the Word Association Test. They received instructions identical to those given to the two instructed groups.

## RESULTS

### Recall

The two sequences of content elements had no differential effect on students' recall of content. This is evidenced in the lack of a statistically significant difference in the groups' mean scores (Table 2).

Table 2

Recall Quiz Scores

| | World-related Group | Concept-related Group |
|---|---|---|
| Number of subjects | 64 | 52 |
| mean score | 12.398 | 12.035 |
| std. dev. | 3.319 | 3.123 |

t = .567 (n.s.)

### Representations of Content Structure

The two-dimensional scaling solutions resulting from the Digraph Analysis of both the World-related and Concept-related scripts (Figures 1 and 2) are very similar in appearance.[2] "Seed," "root," and "stem" are about equally distant from each other and form an almost straight line. "Tissues" and "structures" are also part of this line. "Function" is not closely related to other concepts in either representation. The growth regions (i.e., meristematic, elongation, and maturation regions) form a line roughly parallel to the "seed-root-stem" line. The growth processes (i.e., cell division, cell elongation, and cell maturation) form a third parallel line. "Growth," "cell," and "specialization" are clustered together and seem to be relational elements between growth regions and processes and plant parts (i.e., seed, root, stem). "Monocot/dicot" in the World-related solution is associated with "seed," while in the Concept-related solution it is associated with "seed," "root," and "stem."

The Judges' Graph Analyses of content structure resulted in two-dimensional scaling solutions (Figures 3 and 4) reflecting differences in appearance.

Table 3

Abbreviations of Key Concepts

| | | | |
|---|---|---|---|
| Seed | SD | Specialized (Specialization) | SPC |
| Root | RT | Germinate (Germination) | GM |
| Stem | SM | Monocot/Dicot | M/D |
| Structure(s) | STR | Meristematic Region | MER |
| Tissue(s) | TS | Elongation Region | ELN |
| Function(s) | FN | Maturation Region | MAT |
| Grow (growth) | GW | Cell Division | CLD |
| Cell | CL | Cell Elongation | CLE |
| | | Cell Maturation | CLM |

[2]Scaling Solutions use abbreviations for the key concepts. These are explained in Table 3.

Figure 1 . Two-Dimensional Scaling Solution--Digraph Analysis of World-Related Script

stress=0.126

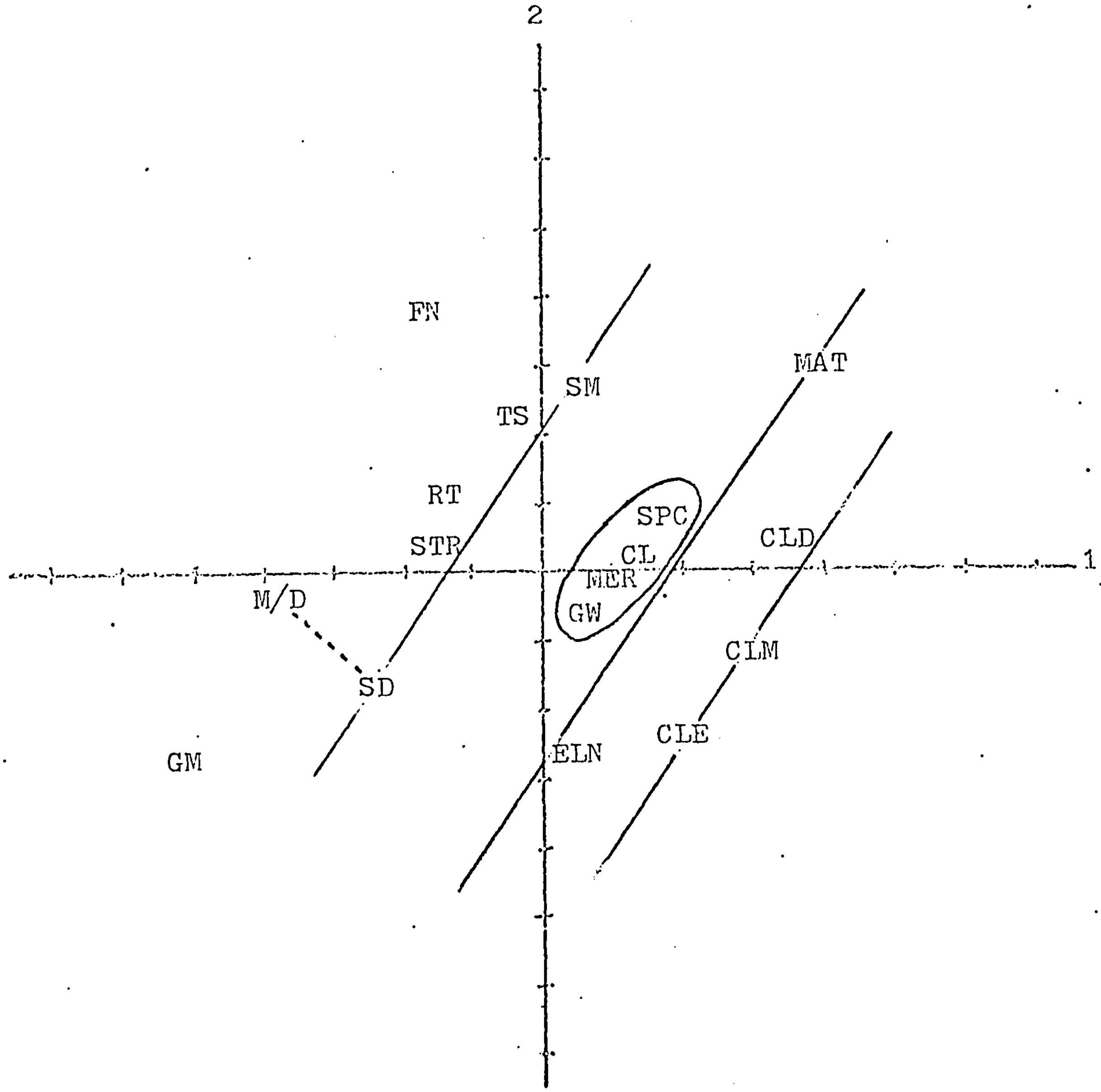


Figure 2 . Two-Dimensional Scaling Solution--Digraph Analysis of Concept-Related Script

stress=0.151

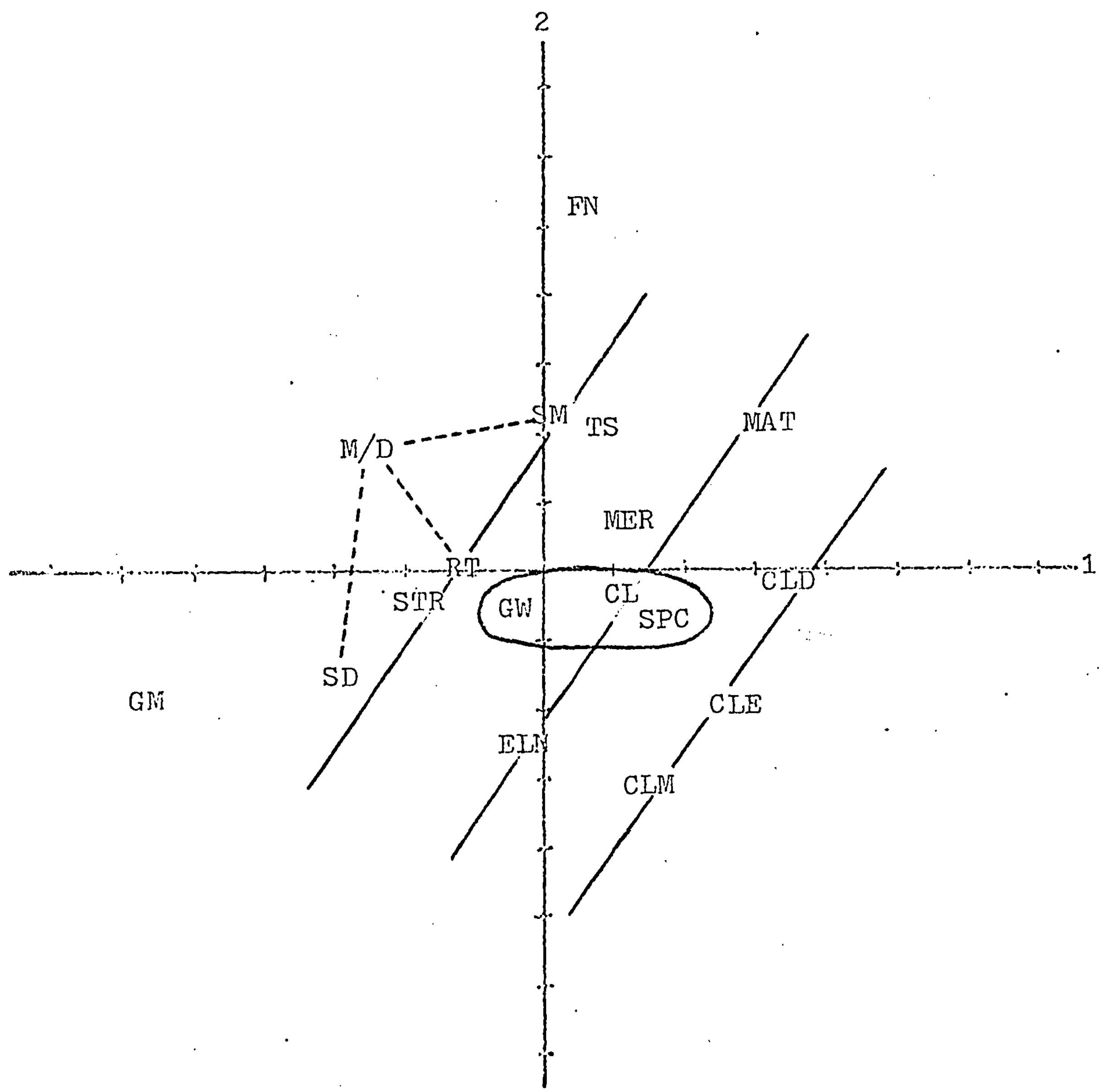


Figure 3 . Two-Dimensional Scaling Solution--Judges' Graph Analysis of World-Related Script

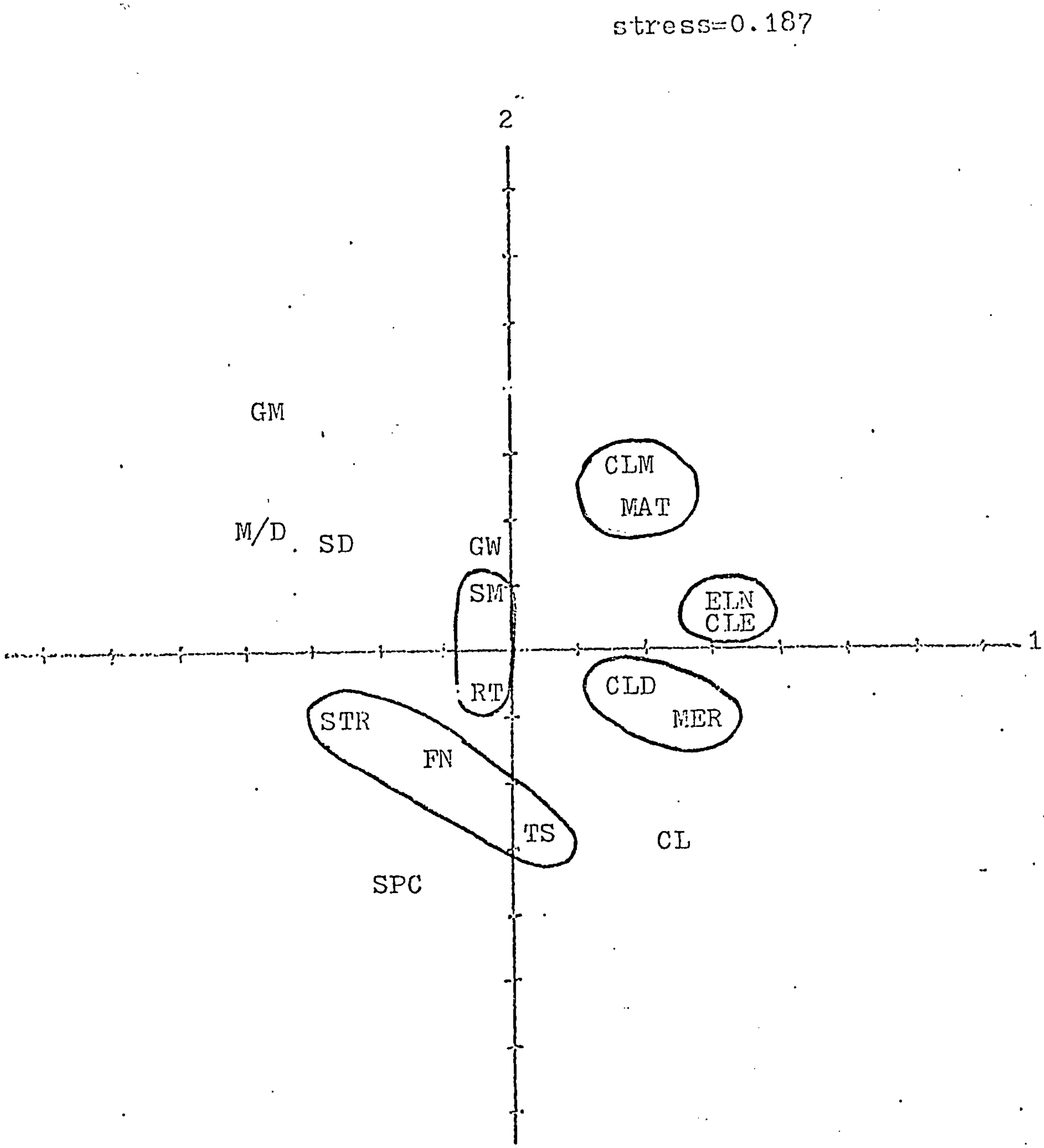
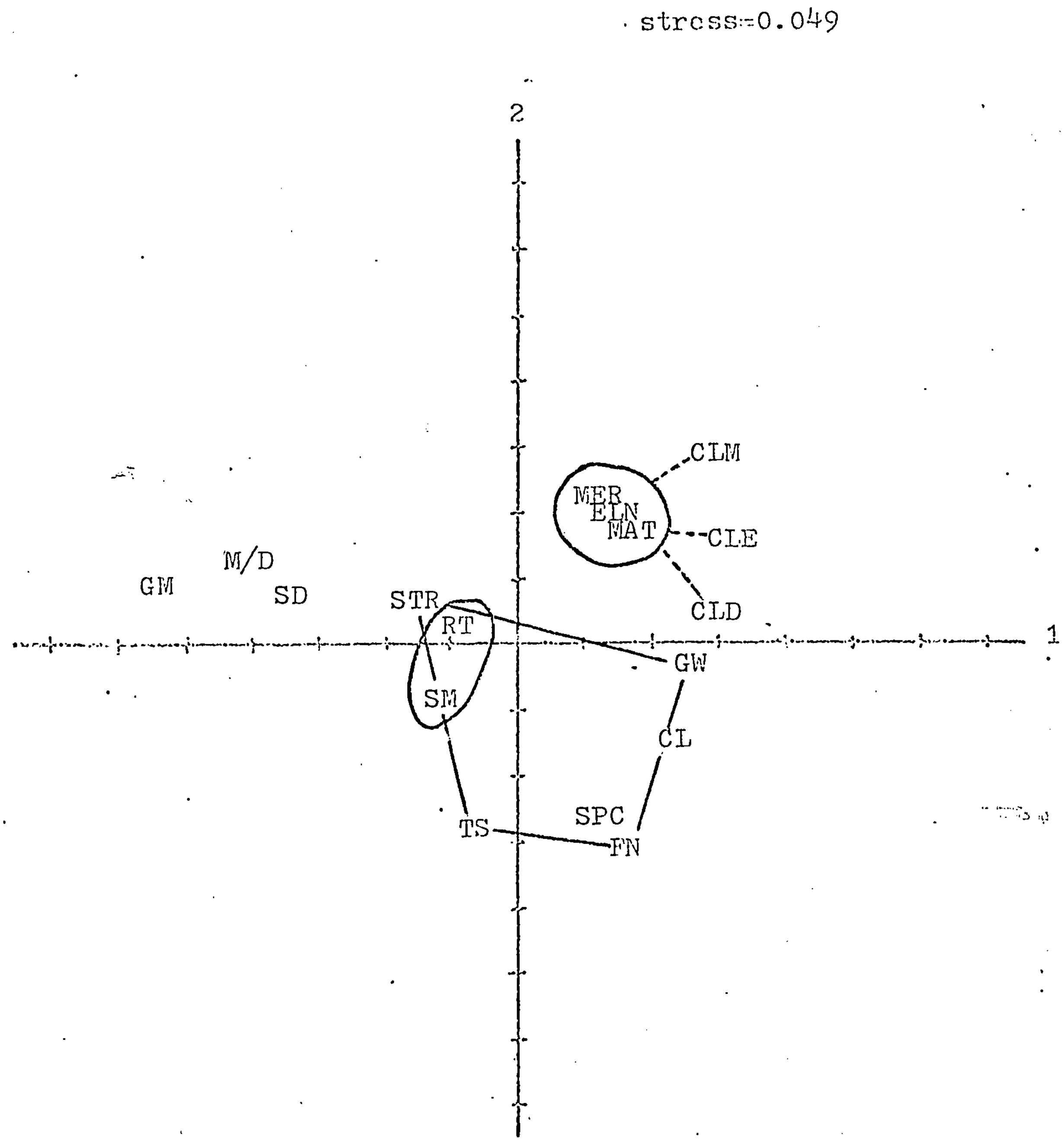


Figure 4 . Two-Dimensional Scaling Solution--Judges' Graph Analysis of Concept-Related Script



The clusters of concepts found in the two solutions, while not radically different, do indicate different structural arrangements. The World-related solution clusters "structures," "functions," and "tissues" closely together, while the Concept-related solution finds "structures," "functions," "tissues," and "growth" occupying what can be pictured as four separate quadrants. The World-related solution pairs a growth region (e.g., elongation region) with its corresponding growth process (e.g., cell elongation). The Concept-related solution, on the other hand, clusters the growth regions very tightly, and around them is the growth processes. "Root" and "stem," closely related in both solutions, seem clustered more with "structures" and "seed" in the Concept-related solution.

Digraph analysis does not discriminate between the Concept-related and World-related scripts as well as does the Judges' Graph analysis. Furthermore, the sequencing and grouping principles employed in the design of the two scripts seem to be clearly reflected in the Judges' Graph analysis but not in the Digraph analysis. This correspondance can be seen in the spread and arrangement of organizing concepts (i.e., seed, root, and stem for the World-related script and structure, functions, tissues, and growth for the Concept-related script) reflected in the scaling solutions for the Judges' Graph analysis.

Representations of Cognitive Structure

Three techniques were used to assess cognitive structure, a Word Association Test, a Clustering Test, and a Graphing Test. For each technique, group data was formed by computing mean distance or similarity matrices, and this group cognitive structure data was represented through the use of Multidimensional Scaling.

Word Association Test. The two dimensional representations[3] of cognitive structure resulting from the Word Association data for the World-related and Concept-related groups (Figures 5 and 6) are very similar. "Stem" and "root" in the World-related solution are very closely related to each other and to "structures." "Stem," "root," and "seed" seem meaningfully related to "structure" in the Concept-related solution. Another subtle distinction between the two representations concerns the concepts relating to growth regions and growth processes. The World-related solution groups these concepts all together, while they form distinct clusters in the Concept-related solution. "Growth," "tissues," "functions," and "structures" are more regular, almost rectangular, in the Concept-related solution while more spread out in the World-related solution.

The baseline group exhibits a two dimensional scaling solution (Figure 7) very different from either the World- or Concept-related solutions. "Seed," "root," and "stem" are tightly clustered in the center of the plot. This solution seems interpretable on a "common knowledge" basis. That is to say, concepts seem to be

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[3]Two-dimensional scaling solutions of high stress are opted for rather than lower stress three-dimensional solutions because a) many of the matrices scaled contain heavily replicated values, b) two-dimensional representations are much more easily visualized. All two-dimensional solutions of stress higher than .20 were also plotted in three-dimensions and compressed to two, the clusters remained essentially unchanged. All the scaling solutions in this study accurately portray the clustering of concepts. Kruskal (1972) adds to this as he notes that

> under some circumstances this table (a verbal-evaluation of goodness-of-fit) is not at all applicable and at best, it is only a rough guide. For example, where data values are heavily replicated, this table is pessimistic and larger stress values are acceptable. For some situations there is simply no experience on which to base any evaluation. (p. 8)

Figure 5. Two-Dimensional Scaling Solution--Word Association Analysis of Cognitive Structure for World-Related Group

stress=0.426

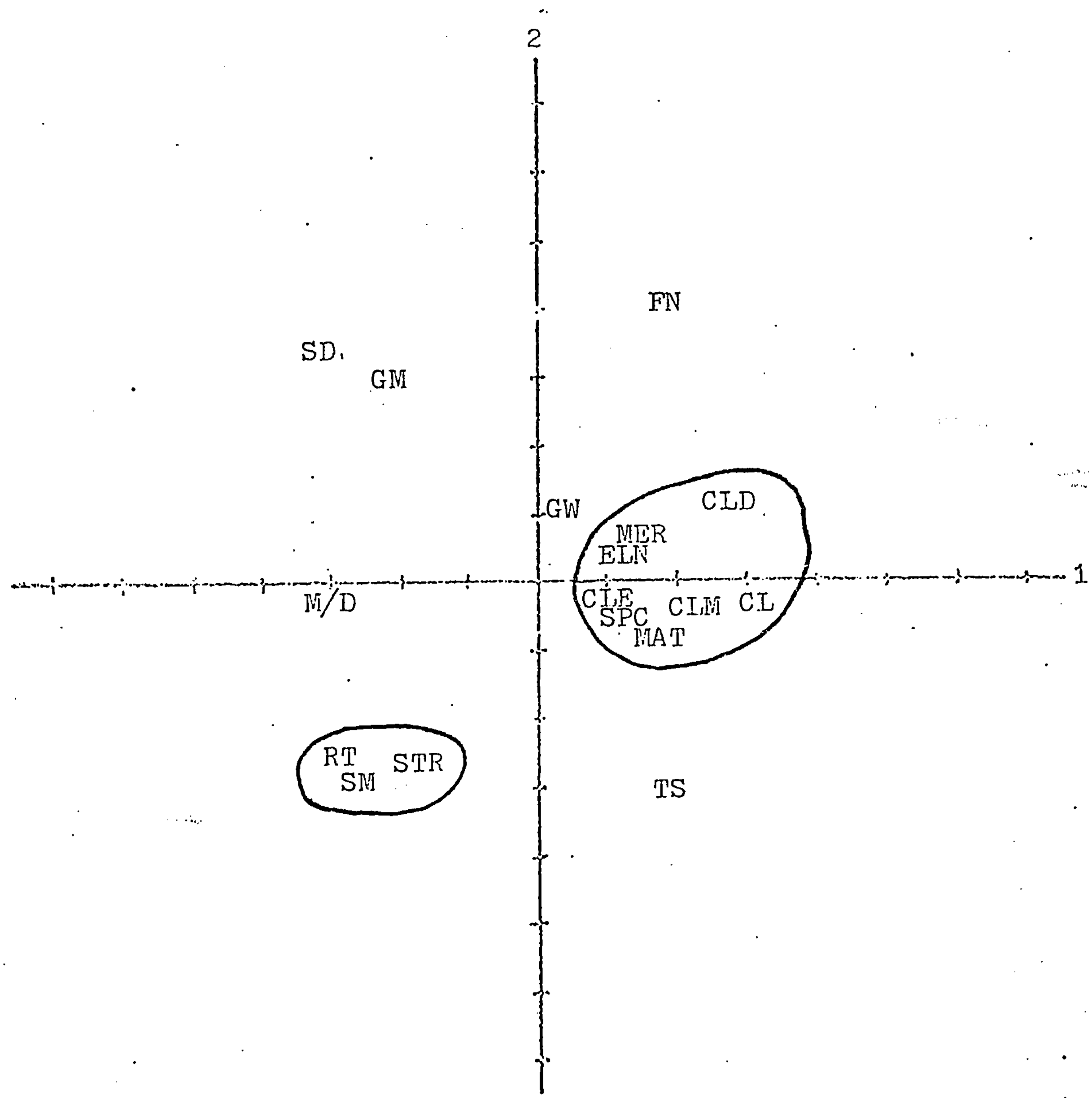


Figure 6 . Two-Dimensional Scaling Solution--Word Association Analysis of Cognitive Structure for Concept-Related Group

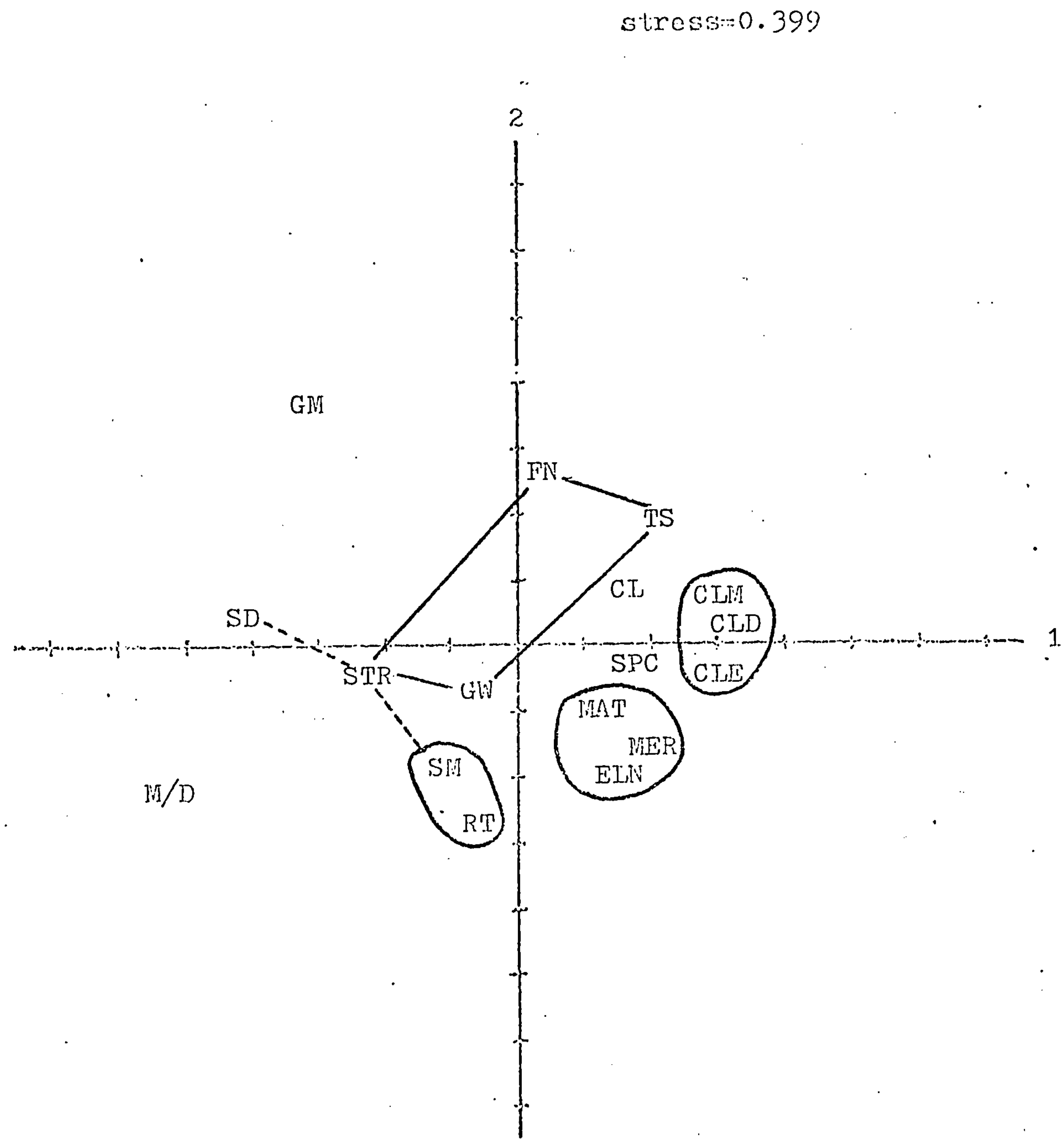
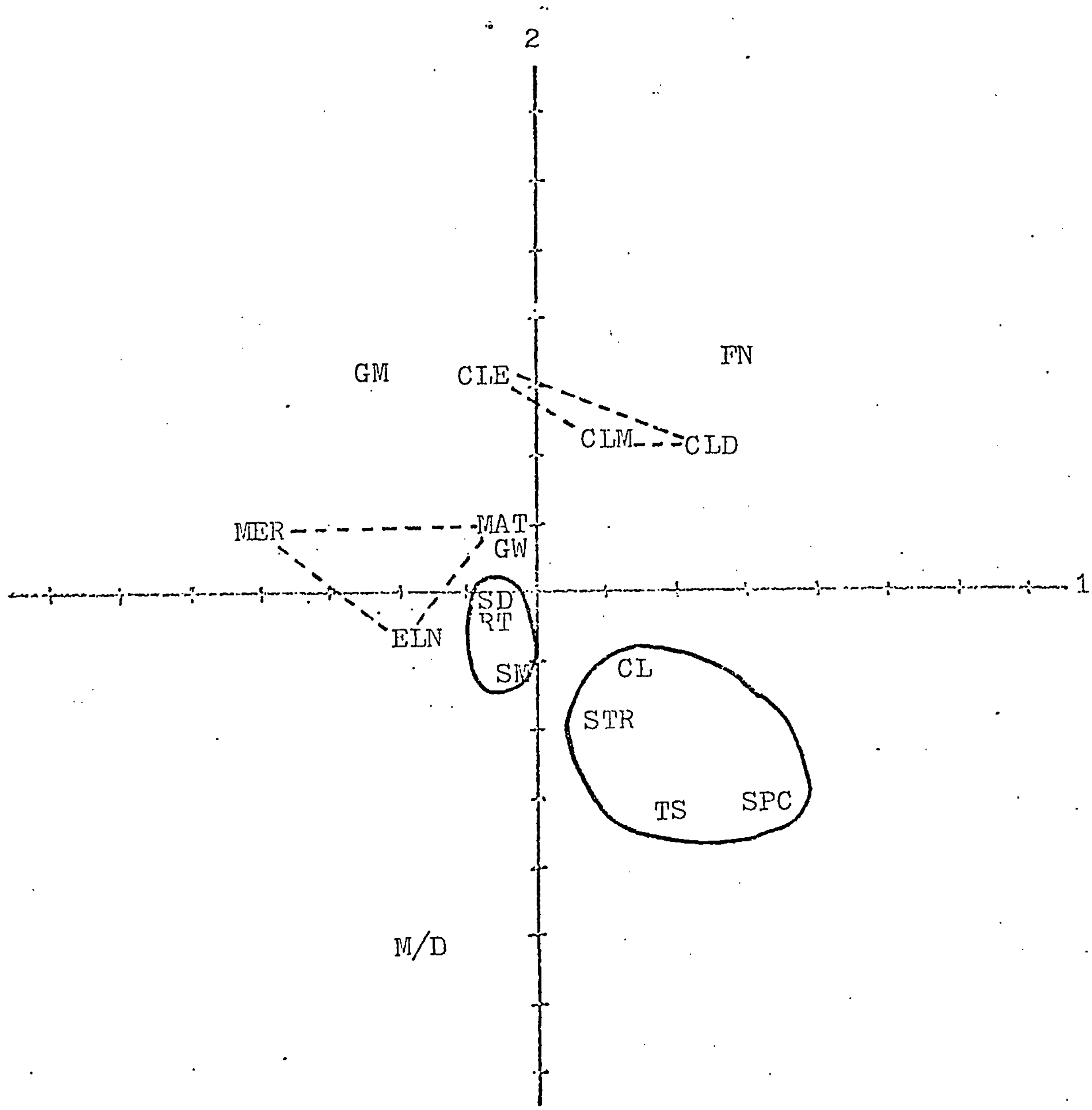


Figure 7 . Two-Dimensional Scaling Solution--Word Association Analysis of Cognitive Structure for Baseline Group

stress=0.399



grouped together by apparent similarities: seeds, roots, and stems are common terms; growth processes and regions sound as though they belong together and, hence, are associated; "cells," "tissues," and "structure" would appear to be at the same level of familiarity to the uninstructed person; that is, they are common terms but not in the same category as seed, root, and stem.

It is certainly safe to claim that the instructed groups evidenced cognitive structure representations very different from that of the uninstructed group.

The Concept- and World-related groups evidence scaling solutions that differ from each other to a slight degree.

Graphing Test. The representations of cognitive structure resulting from the Graphing Test (Figures 8 and 9) reflect many of the features observed in other representations. The World-related solution finds "stem," "root," and "structure" tightly clustered, growth regions and processes forming two distinct clusters, and "function," "growth," and "tissues" taking on a long, almost linear appearance. The Concept-related solution finds "seed," "root," and "stem" spread out; a growth region and its corresponding growth process are related to one another rather than forming two distinct clusters; "functions," "growth," "tissues," and "structures" take on more of a box-like appearance (compared to the World-related solution).

Clustering Test. The representations of cognitive structure for the World- and Concept-related groups resulting from the Clustering Test are nearly identical (Figures 10 and 11). Growth regions and processes form tight clusters. "Root" and "stem" are

Figure 8. Two-Dimensional Scaling Solution--Graphing Analysis of Cognitive Structure for World-Related Group

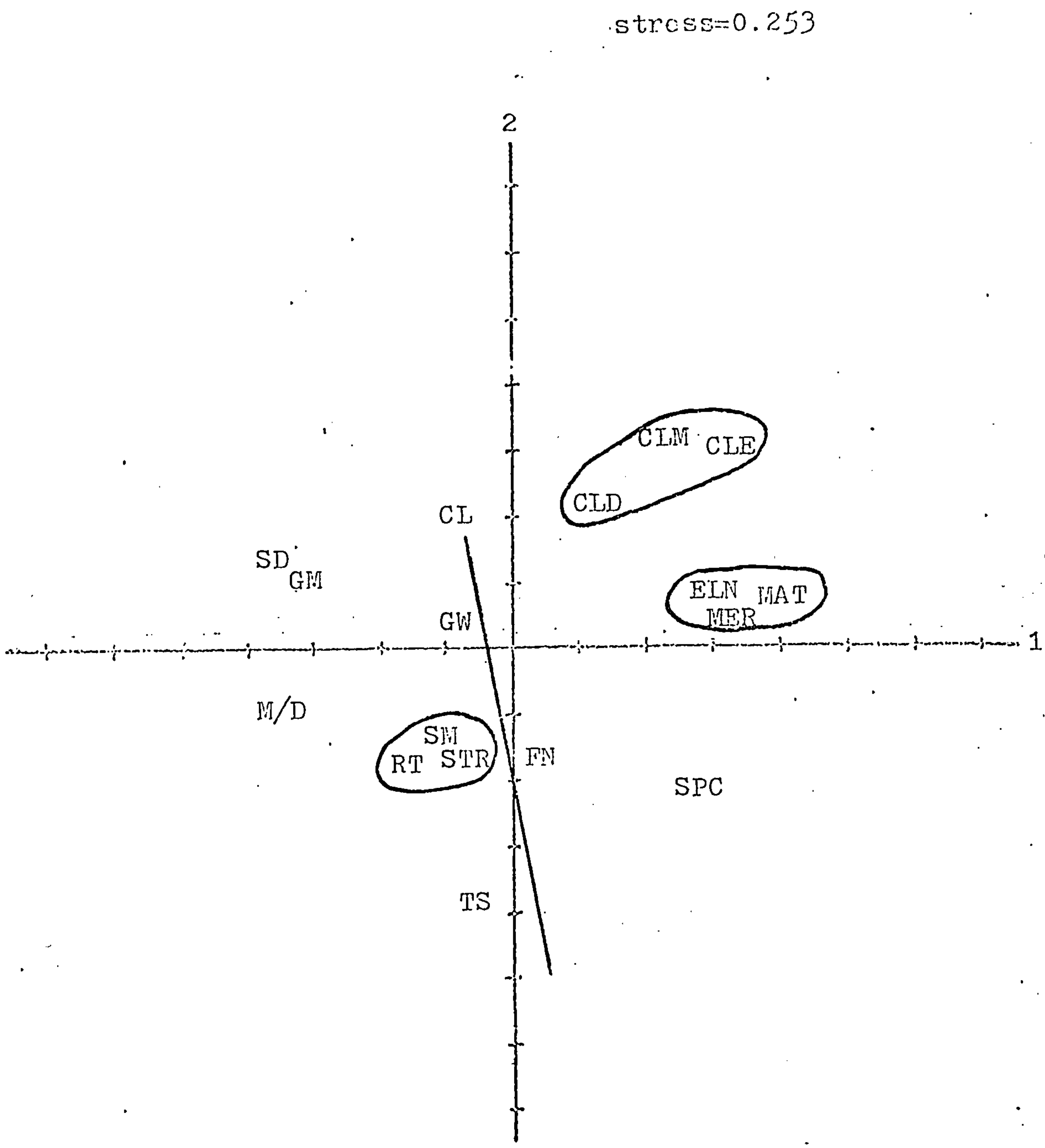


Figure 9. Two-Dimensional Scaling Solution--Graphing Analysis of Cognitive Structure for Concept-Related Group

stress=0.292

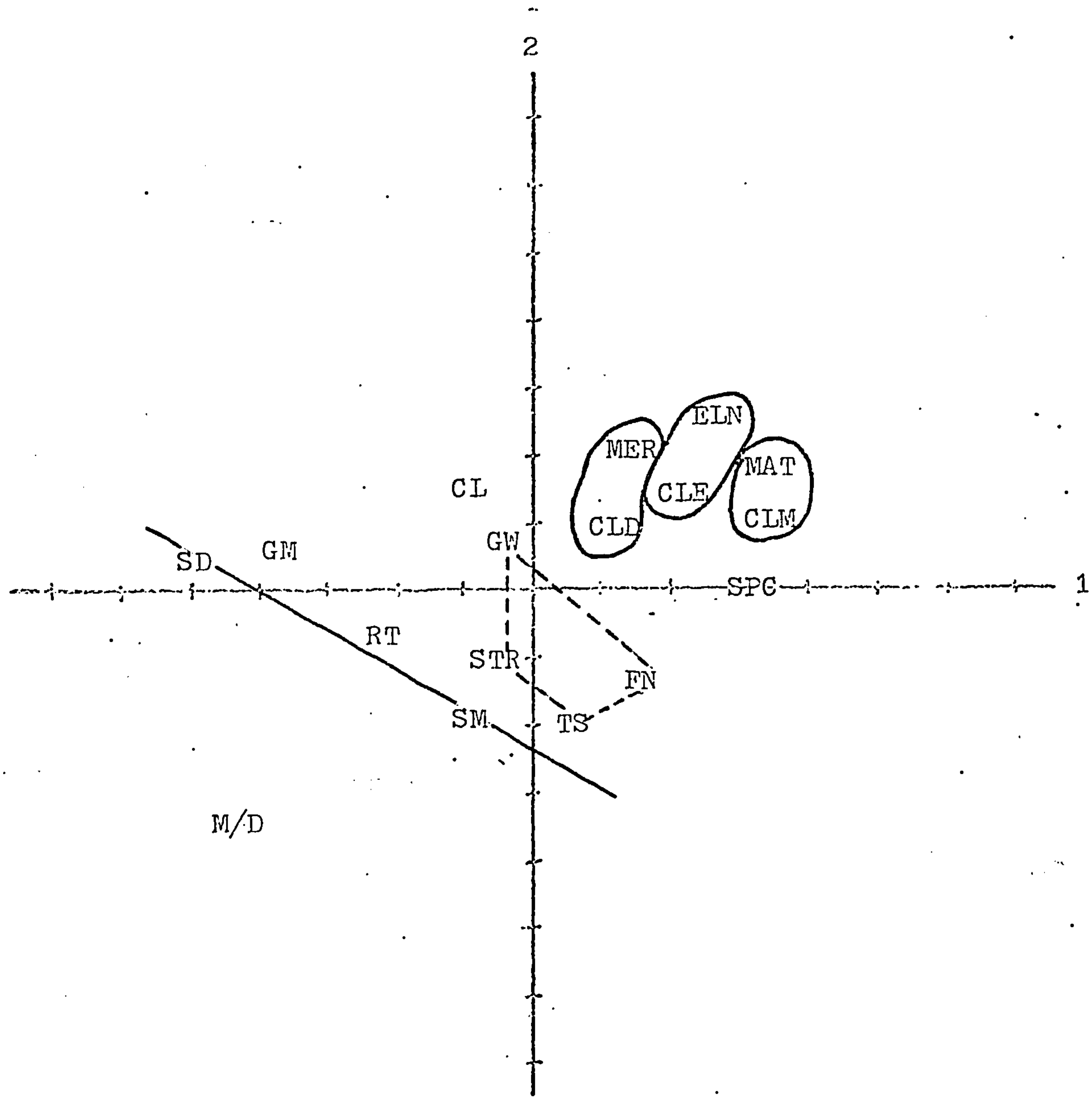


Figure 10 . Two-Dimensional Scaling Solution--Cluster Analysis of Cognitive Structure for World-Related Group

stress=0.359

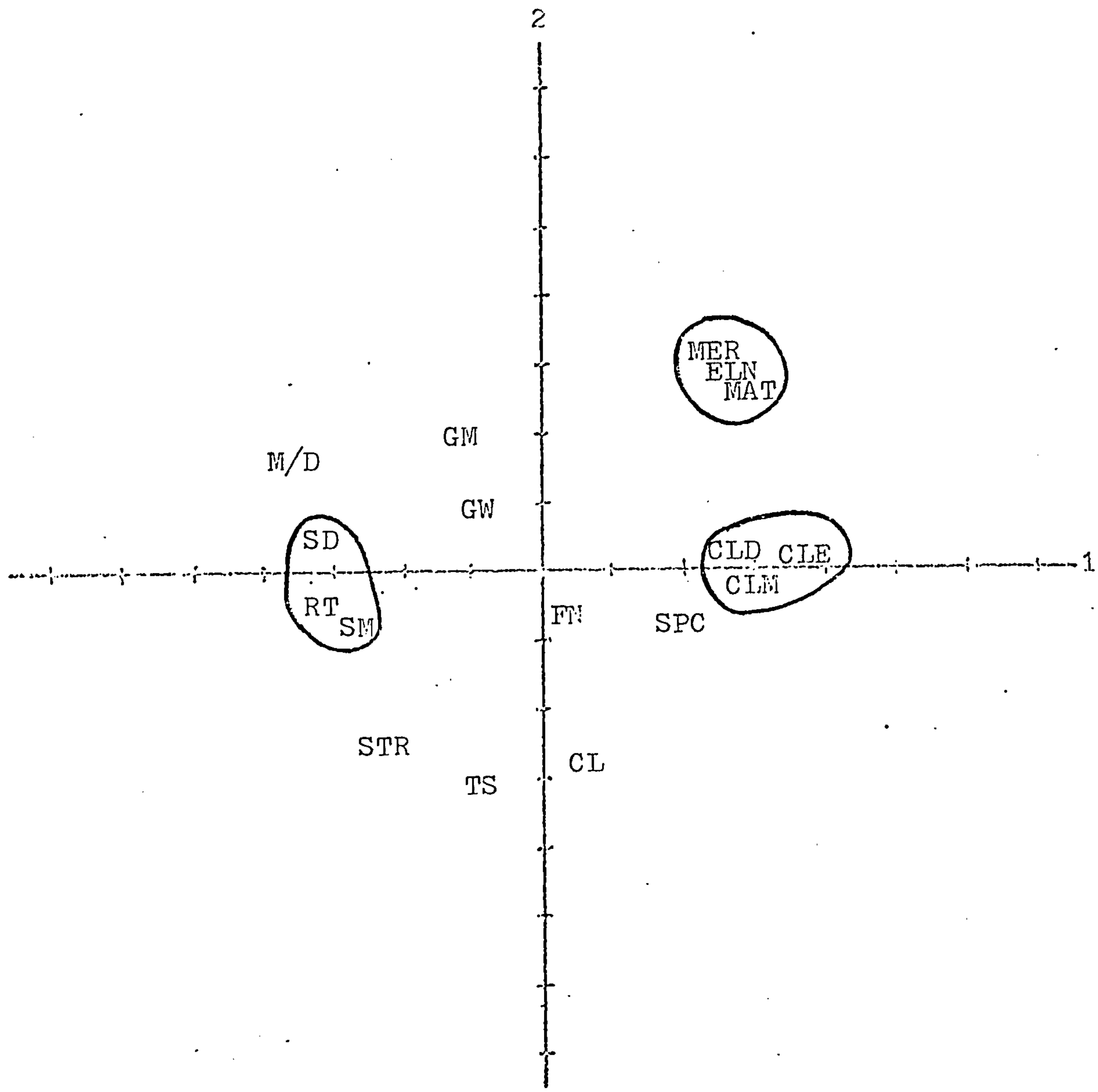
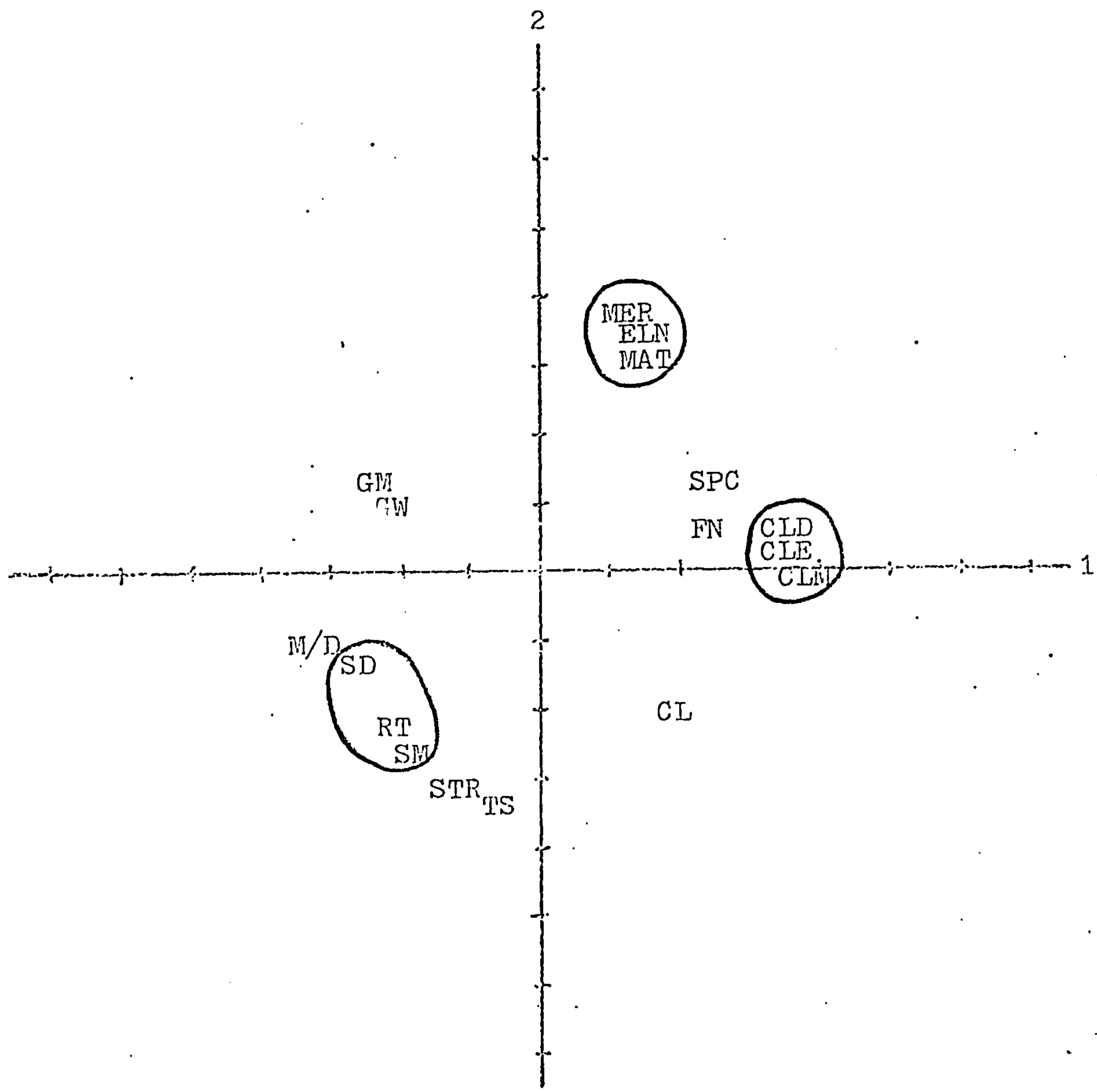


Figure 11 . Two-Dimensional Scaling Solution--Cluster Analysis of Cognitive Structure for Concept-Related Group

stress=0.429



closely related to each other and to "seed." The overall positioning of the concepts is also very similar.

## INTERPRETATION

### Content Structure

Among the questions to be considered pertaining to content structure are the following:

1. To what extent do the techniques for representing content structure discriminate between the two sequences?
2. To what extent do the techniques for representing content structure possess convergent validity?

The answers to these questions are closely related to each other. Digraph analysis of content structure, based on the grammatical structure of the scripts, did not discriminate between the two sequences to a great extent. Judges' Graph analysis discriminated between the two scripts to a greater extent than did Digraph analysis. However, even the Judges' representations of the two content structures were not drastically different.

That two distinct content sequences existed is certain, as they were constructed according to different sequencing and grouping principles. It seems, however, that the two sequences did not represent drastically different content structures. Freedom in creating content sequences is not limitless, particularly when the content is associated with an established discipline (e.g., Botany). This is to say that the conceptual structure of a discipline fixes to some extent the alternate ways in which concepts can be related and still retain their meaning. Both the Concept-related and World-related scripts were designed to portray accurately the subject matter. It seems warranted to conclude that any differences in emphasis or meaning between them were necessarily subtle.

The Judges' Graph analysis seems to be a better technique than the Digraph analysis in discerning those differences in text structure not necessarily reflected in the grammatical structure of the text. It must be pointed out that all four representations were similar and, furthermore, all four representations portrayed a content structure which is meaningful in terms of the clusters and relationships among concepts in the scripts.

Cognitive Structure

The answers to two major questions are at issue in the consideration of the cognitive structure representations. They are:

1. To what extent do the various measures of cognitive structure represent essentially the same construct?

2. To what extent does content structure have an effect on cognitive structure? And do the representations of cognitive structure reflect the differences observed in content structure?

An examination of the clusters in each scaling solution and of the orientation among clusters is quite difficult. In comparing the various cognitive structure representations, consideration of the orientation of the clusters is important. For example, where is "growth," "cell," and "specialization" in relation to the growth regions and processes? Proceeding with this type of analysis the various representations of cognitive structure were found to resemble each other to a great extent. Of all the representations, the Word Association Test scaling solution for the baseline group is most different.

In terms of distinguishing between the two instructional versions, the Word Association and Graphing Tests seem to discriminate while the Clustering Test does not. One distinguishing characteristic of these representations is in the position of "root," "stem," and "structure." For the World-related group's cognitive structure representations these concepts are tightly clustered while for the Concept-related group's representation these concepts are more spread out. Also, with both of these measures, "growth," "structures," "tissues," and "functions" take on a box-like orientation for the Concept-related group's representations.

The cognitive structure representations for both instructed groups resemble each other more than they resemble the representation for the uninstructed group. This interpretation is evidenced not only in an examination of the scaling solutions, but also in the Euclidean distances[4] computed for the cognitive structure representations (See Table 4). These Euclidean distances were scaled using Kruskal's Multidimensional Scaling (Figure 12). This technique presents an easily visualizable picture showing the instructed groups clustered together and the uninstructed group quite separate. This indicates that the cognitive structure measures, while they vary somewhat in their representations, can make dis-

[4]Euclidean distances were used by Shavelson (1971) as a means to compare matrices. They can be conceptualized as representing an absolute distance between matrices.

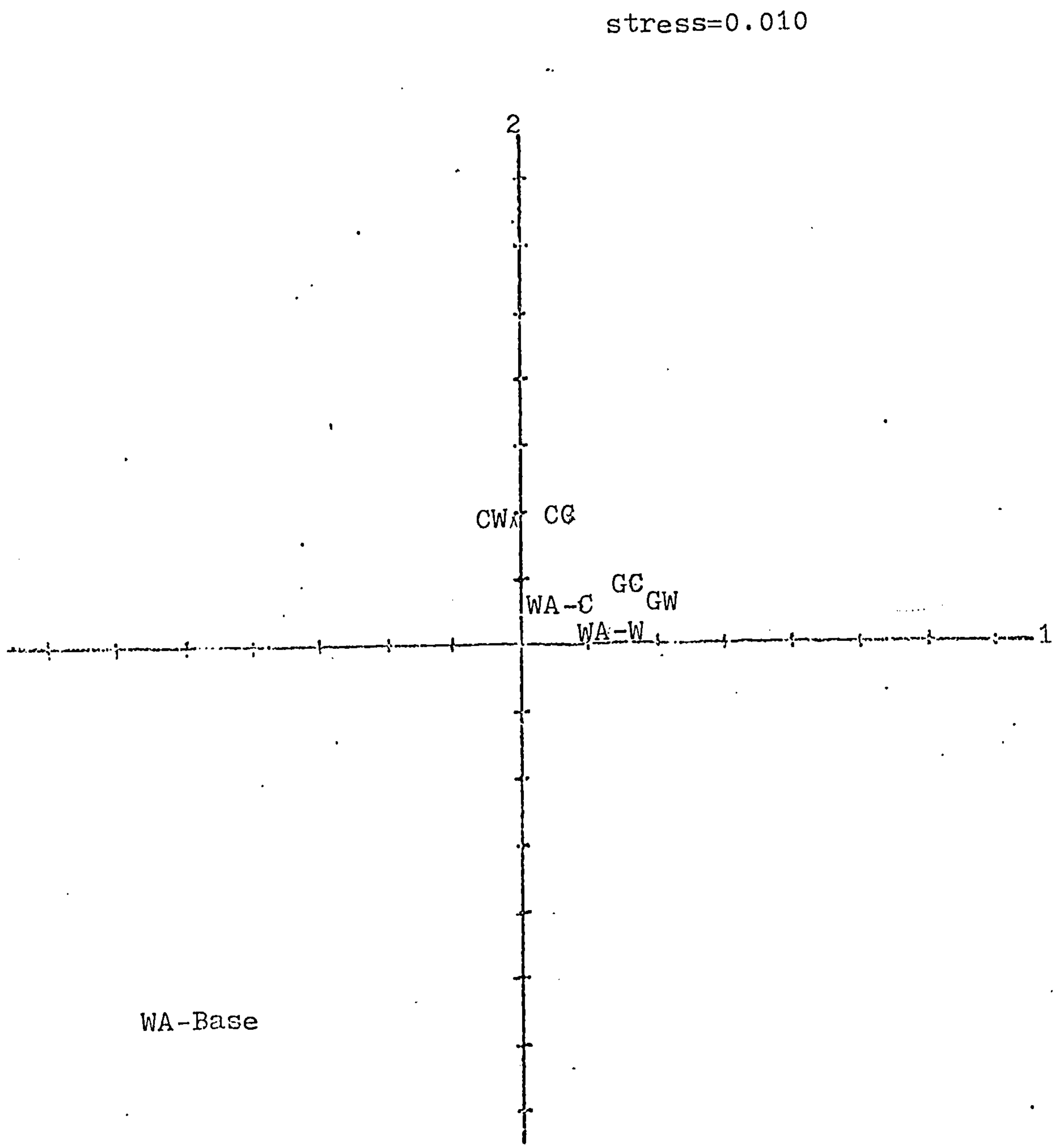
Table 4

Euclidean Distances* for Cognitive Structure Measures

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1-Word Association Baseline | | 9.75 | 9.33 | 10.10 | 9.95 | 9.99 | 9.89 |
| 2-Word Association Concept | | | 3.72 | 5.21 | 6.55 | 3.67 | 4.23 |
| 3-Word Association World | | | | 5.89 | 6.80 | 3.72 | 4.06 |
| 4-Clustering Concept | | | | | 3.85 | 5.03 | 5.12 |
| 5-Clustering World | | | | | | 6.22 | 6.15 |
| 6-Graphing Concept | | | | | | | 1.70 |
| 7-Graphing World | | | | | | | |

*All values x $10^{-3}$

Figure 12. Two-Dimensional Scaling Solution-Euclidean Distances of Cognitive Structure Tests




CW - Clustering Test, World-Related Group
CC - Clustering Test, Concept-Related Group
GW - Graphing Test, World-Related Group
GC - Graphing Test, Concept-Related Group
WA-W - Word Association Test, World-Related Group
WA-C - Word Association Test, Concept-Related Group
WA-Base - Word Association Test, Baseline Group

criminations in cognitive structure of groups that differ to a considerable extent. This result also indicates that content structure has an effect on cognitive structure. This result can be seen by observing that the instructed group's cognitive structure, as a whole, tends to resemble the content structure more than does the uninstructed group's cognitive structure. The Word Association Test and Graphing Test discriminate between Concept- and World-related groups to a greater extent than does the Clustering Test.

Whether the sequencing principles used to construct the scripts are reflected in students' cognitive structure remains problematic. The Judges' Graph analysis portrays a box-like orientation for the concepts of "structure," "tissues," "growth," and "function." This, in turn, is reflected in the Concept-related group's cognitive structure representations for the Word Association and Graphing Tests. There seem to be differences in cognitive structure resulting from the two instructional versions; however, the representations of cognitive structure do not correspond identically with the two content structures as represented by the Judges' Graph analysis.

## CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

The following claims are warranted as a result of this study:

1. Content structure of instructional materials can be varied without resort to the logical versus scrambled comparisons typical of many previous studies.
2. Judge's Graph analysis is a better technique for assessing content structure than is digraph analysis. Presumably this is due to the fact that digraph analysis is based on a surface structure grammar while Judge's Graph analysis is not restricted to surface structure alone.
3. The three measures of cognitive structure evidence convergent validity as they all discriminate between instructed and uninstructed groups.
4. Of the cognitive structure measures, the Word Association test and Graphing test discriminate between the two instructed groups better than the Clustering test.
5. Finally, cognitive structure does grow to resemble content structure as a result of instruction. The differences between the two instructed groups are apparent but subtle. Therefore, any claim that cognitive structure becomes identical with content structure cannot, at this time, be made. This claim requires instruments of greater discriminability. However, the similarities of basic patterns found in this study warrants further work.

Future research in this area should pay particular attention to varying the content structure of treatment materials to a considerable extent and yet not destroying the integrity of the subject matter. Techniques for assessing content structure that attend to deep or semantic structure, need to be developed and/or refined. Thought should be given to using techniques which label the relations between concepts. Techniques for analyzing discourse, such as Frederiksen's (1975), are already quite sophisticated in this respect but are presently too fine-grained for the purposes of curriculum research. Adapting the types of relations that are identified and labelled by these techniques may prove fruitful.

Word association and graphing type techniques seem promising for research in this area. Clustering type measures are suspect in that they may be measuring a somewhat different construct. Cognitive structure is affected by content structure. Future studies need to investigate the consequences of different cognitive structures by using carefully designed transfer tasks. Studies are recommended which provide students with identical content, structured very differently, and investigate the resulting capabilities of students.

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