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IN THE EYE OF THE BEHOLDER: RELATIONAL AND HIERARCHICAL STRUCTURES IN CONCEPTUALIZATION

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ABSTRACT

This paper describes the translation from hierarchical structures, operationalized as outlines, to relational structures, operationalized as the maps derived from a multidimensional scaling and cluster analysis procedure. Using a variety of models that represented different assumptions about the relationships within the outline, similarity matrices were derived for a sample outline. The resulting maps were examined to see how well they reflected the outline. The three best reflections are presented here. The ability to translate between hierarchical and relational structures will give program planners and evaluators greater flexibility in both the sources for and the representation of a conceptualization.

Information about interrelationships between ideas or objects is usually presented in either hierarchical or relational form (Novak & Gowin, 1984). Outlines and narratives are examples of hierarchical forms. Maps and correlational tables are common forms of relational information. Both hierarchical and relational representations of information have advantages and disadvantages. For example, outlines and narratives can be more detailed than maps without losing clarity, while the information on maps can present a lot of information without the use of a lot of words. This facilitates the access to the information by the beholder of the map and also gives him/her more responsibility for the interpretation of the information.

The purpose of this paper is to explore the possibility of developing models which allow us to translate from one form to another. The ability to generate hierarchical structures from concept maps has already been demonstrated by Trochim and Linton (1986). They derived an outline from a concept map by first grouping the entities in a cluster tree based on a hierarchical cluster analysis. Then, subheadings and headings for the groups of entities were obtained from the names of map clusters and regions. These names had been determined by the respondents in the process of interpreting the concept map. Since Trochim and Linton (1986) have already described the transition from a relational form to a hierarchical form, the central focus of this paper is the translation of hierarchical information to a relational representation.

The ability to make this kind of transition would be valuable for many reasons. At a theoretical level, it is an interesting question in itself. Researchers have already linked the two different forms of representation to different cognitive styles and perhaps to the dominance of one brain hemisphere over the other (Rico, 1983).

Related to its theoretical value is the suggestive value of developing models for moving from one representational form to another. By viewing the same problem using different structures people may see the issues differently. For example, data from field notes may be organized in a hierarchical (e.g., outline) fashion, but before writing a paper one could display the data in a relational form (e.g., a concept map) as a heuristic device to suggest different ways of organizing the paper. The translation model could free the data from the hierarchy and allows the researcher to view it in new ways.

Another reason for pursuing this research is that by developing models of this type we may be able to utilize the output of computerized outlining programs directly to produce pictorial representations. In the development of concept maps, outlining, computer assisted or not, could be used as an alternative to unstructured sorting.

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Finally, this research can be useful in planning and evaluation. Most programs are based, at least in part, on a hierarchy of goals, objectives, and tasks. This hierarchy is represented in organizational charts, reports, and other program documents. Using these documents as input in hierarchical form, a computer program could be devised to automatically translate that hierarchical information into relational or map form. In program planning, the hierarchical information gathered from program documents and displayed in relational form can be used to rethink programs. Information may be more easily synthesized in a relational form than in the form of a written text, and it is also more easily discussed and reorganized. Once the relationships displayed have been discussed, new information could be added to the system, and a new hierarchical representation could be generated.

In the evaluation of a program, maps derived from the hierarchical information in program documents could be checked for validity against maps generated from relational information given by the staff or clients about some aspect of the program. The ability to move from hierarchical to relational forms of representation would also facilitate the pictorial representation of evaluation results.

DEVELOPING THE MODELS

While the ultimate goal of this research is to develop models for moving easily from one form to the other, this paper focuses on the translation of hierarchical information to relational structures. Hierarchical structures were operationalized as outlines because of the simplicity and utility of outlines in the reduction of more complex hierarchical data. Relational structures were operationalized as the maps that are derived from the multidimensional scaling and cluster analysis techniques described in the first paper in this volume.

In order to find a model that would enable us to develop models to generate a map that was a fair representation of an outline, the following procedures were used. First the relationships between entities in an outline were established according to several major assumptions. Then similarity matrices based on each set of assumptions were derived. Finally, multidimensional scaling and cluster analysis techniques were used to generate the maps based on the matrices. To illustrate the models we explored, an outline of "Threats to Validity" was used. This outline, derived from the familiar taxonomy described by Cook and Campbell (1979), is shown in Figure 1. Three sets of models are described here. While the models differ in their assumptions, each uses the same counting rules to arrive at the similarity matrix. These rules are:

1. In each model, the line that directly connects two entities without passing through a third entity equals one path.
2. The distance between any two entities in the outline is equal to the number of paths between them.
3. The similarity between any pair of entities is equal to the number of paths between them subtracted from the largest number of paths possible between any two entities.

Each of the three models are considered in order below.

Model 1: Hierarchical Model

The first model is depicted graphically in Figure 2. To see how this model works, consider how the counting rules were applied to generate a similarity matrix for the elements in the outline according to this model. An example of a path is the line between "Internal Valid-

<u>THREATS TO VALIDITY</u>

I. Internal Validity

- **A. THREATS TO CONCLUSION VALIDITY**
  1. Low Power
  2. Violated Assumptions
  3. Unreliable measures
- **B. THREATS TO INTERNAL VALIDITY**
  1. Statistical Regression
  2. Selection
  3. History

II. External Validity

- **A. THREATS TO CONSTRUCT VALIDITY**
  1. Inadequate preoperationalization
  2. Mono-operation bias
  3. Mono-method bias
- **B. THREATS TO EXTERNAL VALIDITY**
  1. Interaction of selection and treatment
  2. Interaction of setting and treatment
  3. Interaction of history and treatment

Figure 1. Outline used to test models.

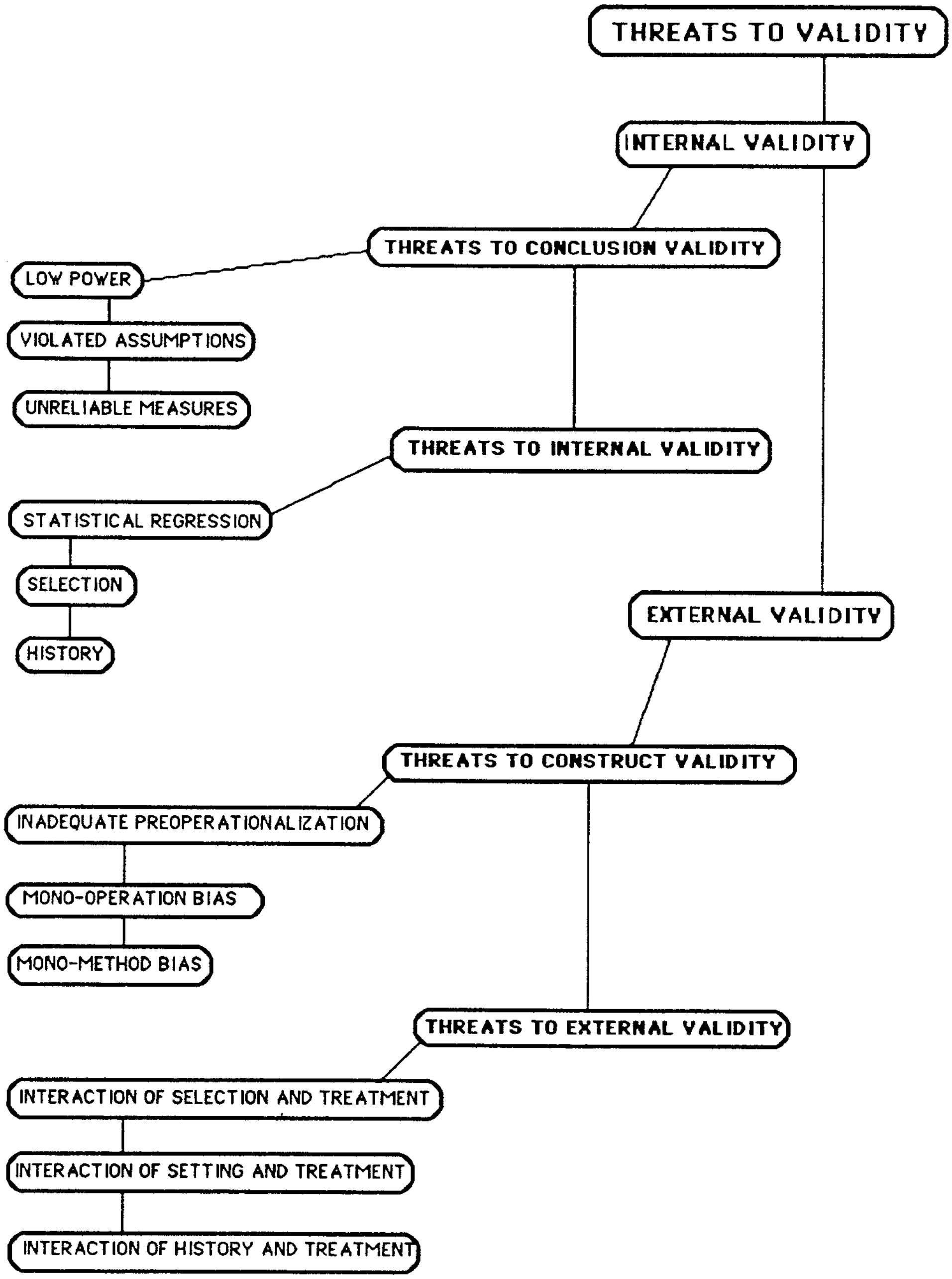

Figure 2. Hierarchical model.

ity" and "Threats to Conclusion Validity." Thus, the distance between "Internal Validity" and "Statistical Regression" is equal to three paths. The similarity of "Internal Validity" and "Statistical Regression" is equal to the greatest possible distance between any two entities in the model, which is twelve, minus the distance between these two, which is three, so the similarity is equal to nine. The model in Figure 2 is a simple hierarchy which assumes that the concept "Internal Validity" is closer than "External Validity" to "Threats in the Validity;" that "Mono-operation Bias" is closer than "Mono-method Bias" to "Threats to Construct Validity"; and so on. In more general terms, the model assumes that the first subheading is more related to its major heading than the second, and so on.

The map based on this model derived from the similarity matrix is shown in Figure 3. The map seems to be a fair reflection of the rather strict hierarchical assumptions made. However, one might have expected "Threats to Validity" to be to the left of "Internal

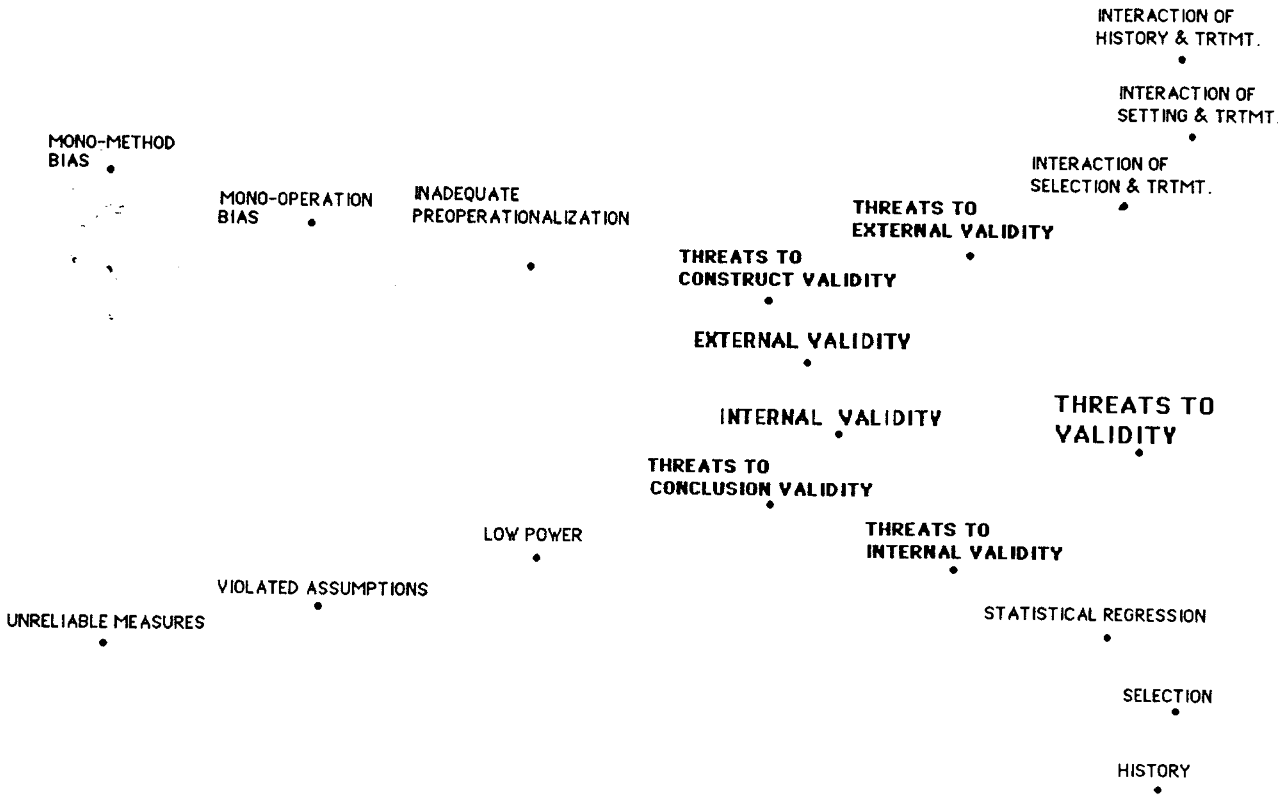

Figure 3. Map based on hierarchial model.

Validity" and "External Validity" since this would place it closer to "Threats to Conclusion Validity" and "Threats to Construct Validity" as it is in the model. Not only is the placement of the main topic not completely congruent with the model, it may not be the best reflection of the outline. One can think of the main topic as being "central" to the outline. It should therefore be in the center of the map.

Model 2: Digraph Model

The second model, shown in Figure 4, addresses this issue. The assumptions of this model are based on Waller's (1976) discussion of directed graphs, or digraphs. Unlike the first, totally hierarchical model, the second model displays subheadings under a heading as equally distant from all other headings. Thus, the main topic is centrally related to the subdivisions. For example, in this model "Internal Validity" and "External Validity" are considered equally distant from the overall heading of "Threats to Validity." As a result, the map derived from this model should have "Threats to Validity" in the center. An additional advantage is that, because of the symmetry of this model, much less information than that used in the hierarchical model is required to derive the similarity matrix.

The map derived using the second model can be seen in Figure 5. While the màp based on this digraph model has the main topic in a central place and otherwise sensible placement of the entities, it is less useful than the map based on the hierarchical model simply because the entities at the most specific level (e.g., I.A. 1-3) are not differentiated. For this reason, the next map was based on a set of assumptions that combined the digraph and the hierarchical models.

Model 3: Hybrid Model

The third model, combining the hierarchical and digraph models, is shown in Figure 6 and the resulting map in Figure 7. This model is identical to Model 2 except that at the lowest subheading level the subheadings are considered hierarchical as in Model 1. This last restriction will force the lowest subheading entities to be differentiated on the map. The resulting map is a better representation of the outline than that obtained from the other two models. Each entity is placed separately and symmetrically on the map in a way that reflects assumptions made about the structure of the outline.

In addition to the maps and models displayed here, other models were attempted using even less information than that given in the digraph model. However, the results were not especially useful and those attempts were abandoned.

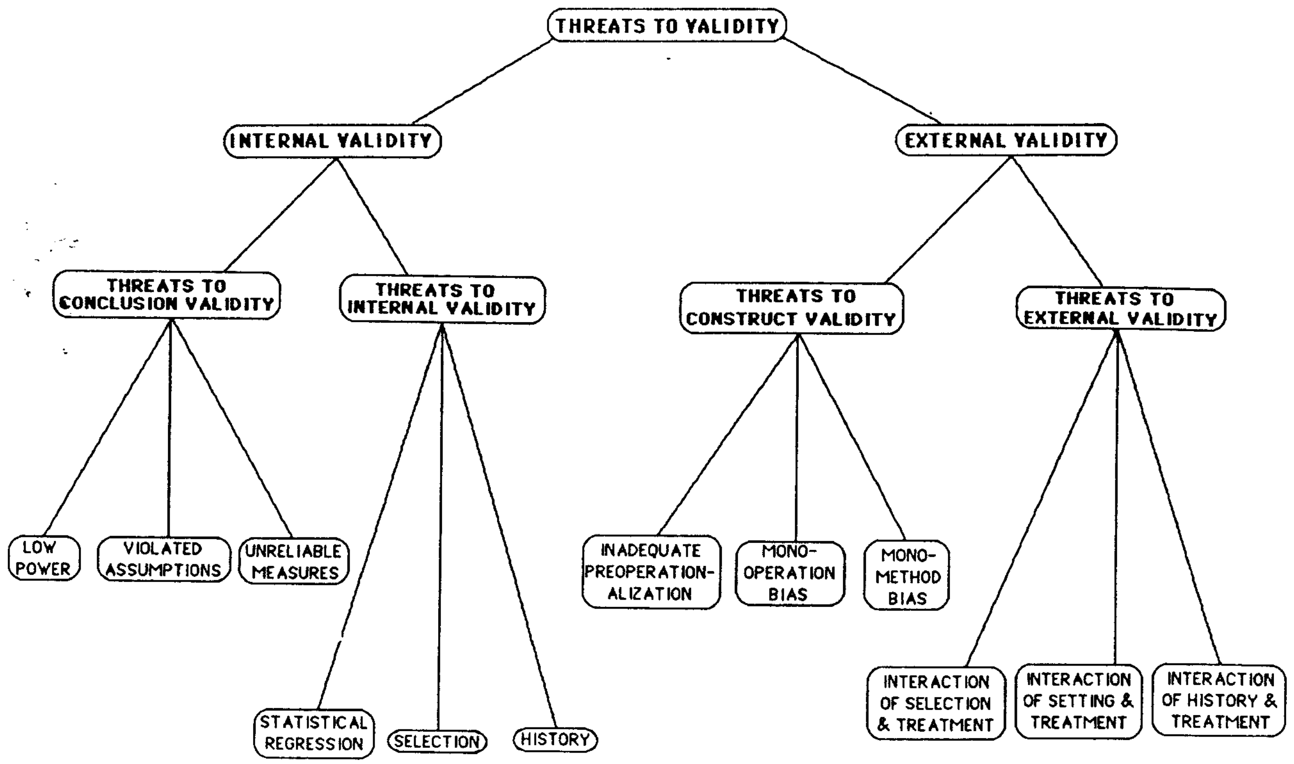

Figure 4. Digraph model.

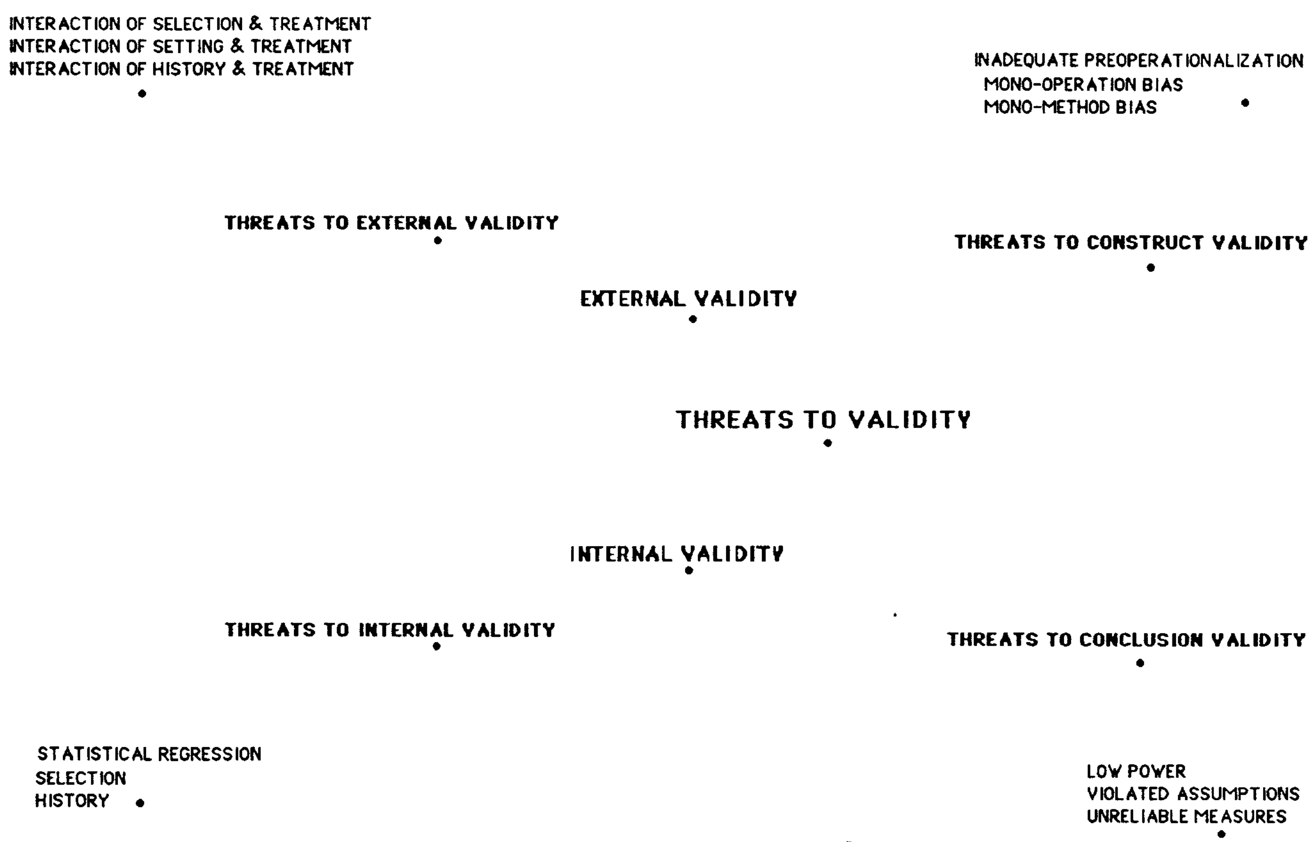

Figure 5. Map based on digraph model.

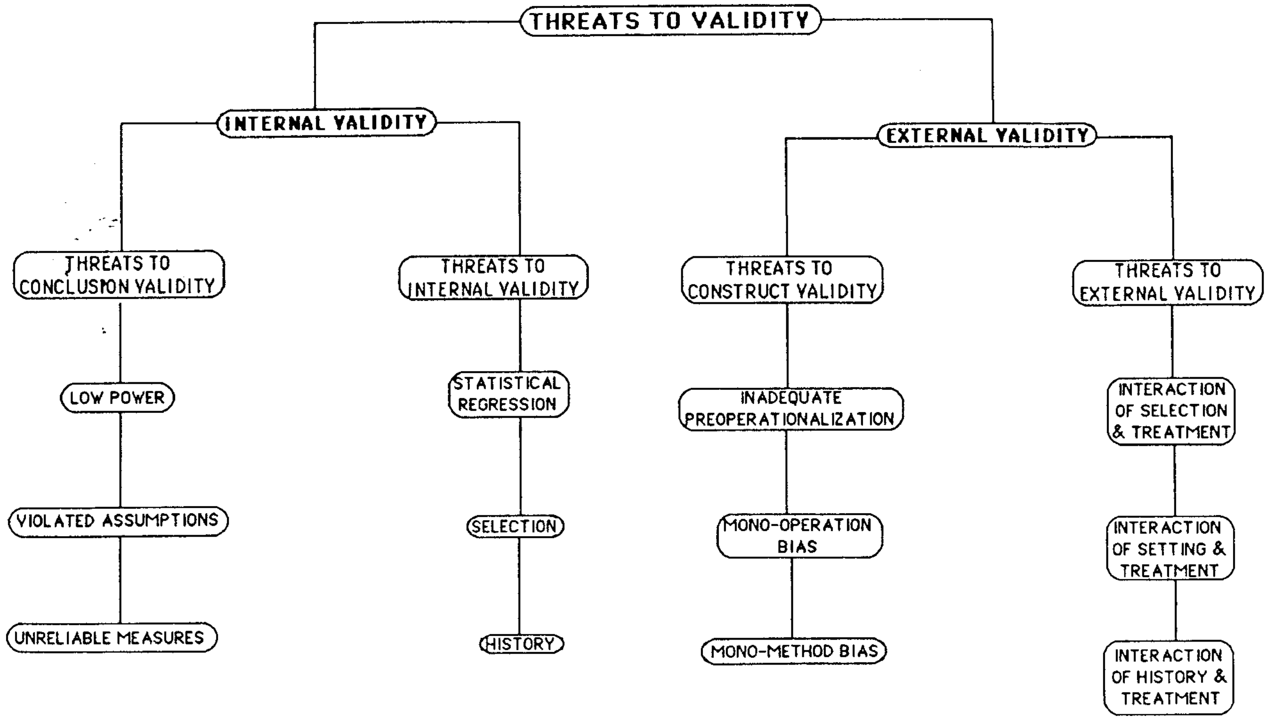

Figure 6. Hybrid model.

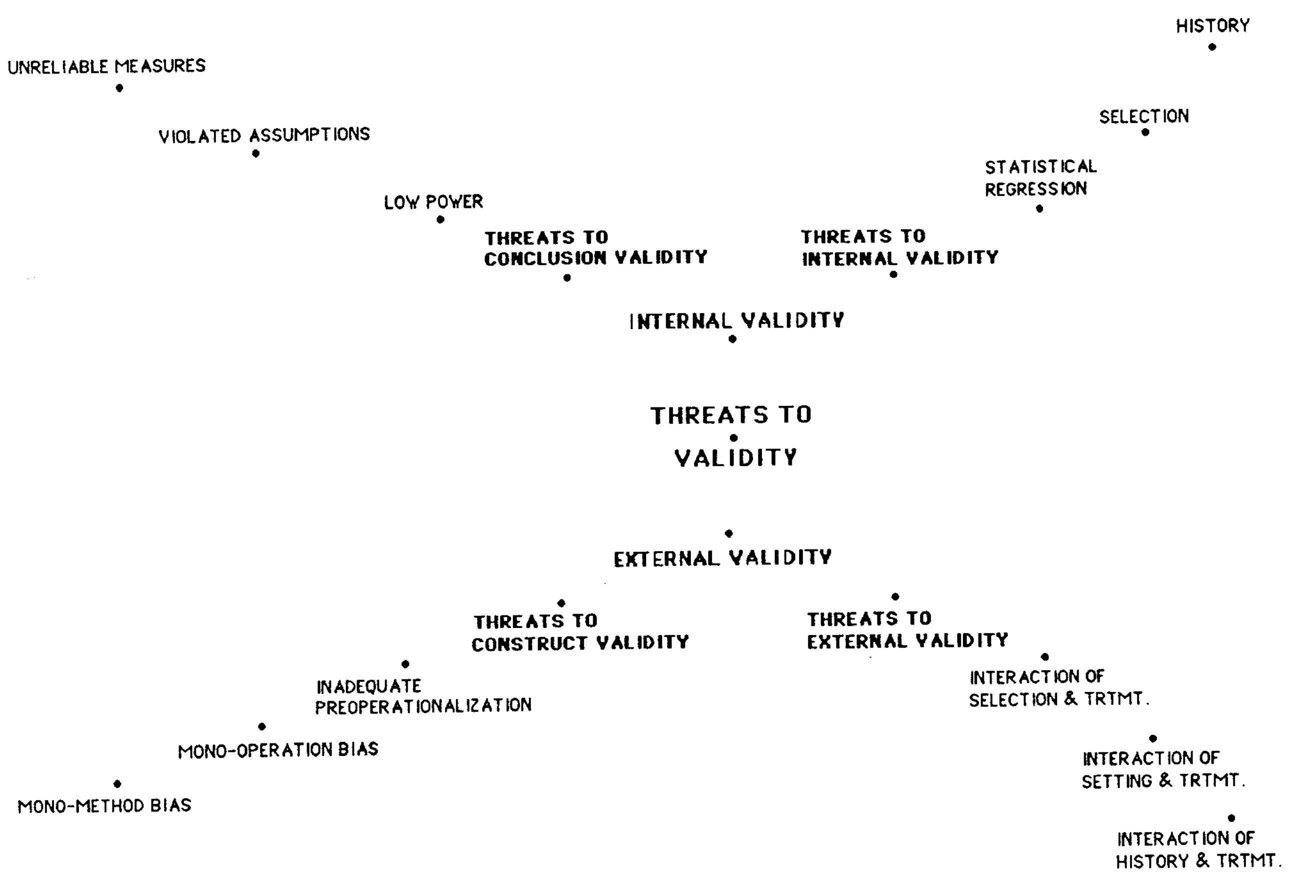

Figure 7. Map based on hybrid model.

CONCLUSIONS

Our general conclusion is that the best model is one which combines both the hierarchical (Model 1) and digraph (Model 2) approaches. The digraph approach is used overall, and only the last nested group under each branch of the outline is broken down hierarchically. This is done so that these lowest-level entities will be distinguished from each other on the map.

While this effort is just the beginning of a wider attempt to develop models to translate automatically from one form of representation to another, it is quite promising. In the future, techniques like this may be used to help program planners and evaluators involve stakeholder groups in developing a unified conceptualization of the program. Each person would use a common set of entities and place them in outline form to reflect their view of superordinate-subordinate relationships within a set of entities. The similarity matrices derived from the outlines could then be aggregated, and a single map would be generated. This map would be a single representation of the participants' conceptualizations of the program. New information from discussions of the map could be added and then translated back into outline form for the writing of a report.

Future work in the development of this technique will include the programming of the digraph-hierarchical model for use with the multidimensional scaling and cluster analysis procedure and the application and testing of the method with more complex and realistic hierarchical structures.

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