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Recent advances in the analysis of a repertory grid

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This paper extends a previous survey of techniques for the analysis of repertory grids. It compares principal component analysis, Q-analysis, FOCUS and a new logical technique ENTAIL on some examples, and discusses the similarities and differences in the results.

The computer analysis of repertory grids has become a technique of great interest and wide application in recent years. Shaw (1980*b*) reviewed some of the general issues in psychological scaling with reference to repertory grids, including the problems of the use of scales by individuals and the interpretation of the meaning of these data by the psychologist. In this paper we first illustrate the relationship between some commonly used methods of analysing such data by comparing them on an example of a binary grid. This shows the high degree of correspondence between the methods in the clusters produced. We then go on to illustrate a new method of grid analysis recently developed (Gaines & Shaw, 1980), and show that it subsumes and extends the previous techniques. A further example is given to show the application of this new method to rating scale data.

Grid analysis based on distance measures

Figure 1 is a repertory grid from Shaw (1980*a*, p. 79) showing Jane's allocation of 12 acquaintances to the poles of eight constructs. It is a particularly good illustrative example because Jane has given far more background explanation to the poles of her constructs than is usually available and this makes it easier to assess the prima facie *meaningfulness* of any analysis. The only difference between Fig. 1 and Fig. 6.4 in the book is that Shaw uses the letter 'X' for the assignment to the left-hand pole and the letter 'O' for the assignment to the right-hand pole, whereas we have used the numbers '1' and '0' respectively. This change to numerals is deliberate because we wish to examine how the values in the grid may be viewed in two ways: firstly as numerical values; and then as logical values.

We will concentrate initially on the relations between the constructs in a grid such as that shown in Fig. 1. For any given construct we may regard the numbers in the grid as a *vector of values* giving the assignment of each element in turn to one or other of the poles of the construct. From this point of view each construct becomes represented as a point in a multidimensional space whose dimension is the number of elements involved. The natural relation to examine between constructs is then the *distance* between them in this space. Two constructs which are zero distance apart are such that all elements are construed in the same way in relation to them and hence we might infer that they are being used in the same way – in some way they are *equivalent* constructs. For constructs which are not equivalent we may analyse the entire constellation in space to determine a set of axes such that the projection of each construct onto the first axis accounts for most of the distance between them, the projection on the second axis accounts for most of the remaining distance, and so on. This is a *principal components analysis* of the construct space (Slater, 1977). We may also group constructs together that are close together in space using a variety of techniques. These are all some form of *cluster analysis* (Duran & Odell, 1974).

All of the techniques based on such a numerical spatial view of construct structures depend on the notion of constructs being equivalent if they are represented by the same point in space and somehow *nearly equivalent* if they are represented by points close to one

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			Elements											
	1	0	1	2	3	4	5	6	7	8	9	10	11	12
C1	*Intensity*. They both are interested in other people. Concerned with world problems. Ambitious. Slightly detached.	*Humorous*. Creative. Unconventional approach to work & relationships. Excitable.	1	1	0	0	1	0	0	1	0	1	0	0
C2	*Individualistic*. Musical. Calm (exteriorally). Unconventional. Non-aggressive. Loyal. Interested in myth & fantasy. Homely. Land-loving. Tending toward introversion. Unusual humour.	*Self-aware*. Controlled. Sporting. Experienced in relationships. Attracted to sophistication & the exotic. Extraverted. Light-hearted.	0	0	0	0	1	1	0	0	0	0	1	0
C3	*Generous*. Interested in history. Slow living. Perfectionist in work. Unusual relationships.	*Direct*. Political. Super-active. Strong integrity. Committed.	0	0	0	0	1	1	1	0	1	0	1	0
C4	*Ambitious*. Questioning. Quick minds. Confident. Interested in 'society's ills'.	*Artistic*. Capable. Gentle. Romantic. Exploratory.	1	1	1	1	0	0	0	1	0	1	0	1
C5	Outdoor enthusiasts. Anxious to succeed. Anxious about success with other sex. Active. *Enigmatic*. Need mental stimulation	Creative. *Enjoys comfort*. Relaxed.	1	1	1	1	0	0	0	1	0	0	0	1
C6	Enjoy intellectual discussion. Difficult to understand initially. City-livers. *Seek challenges*. Insecure backgrounds.	Affectionate. Humble. Sensitive. Musical. Involved with those immediately around. *Compassionate*. Philosophical.	0	1	1	1	0	0	1	1	1	1	0	1
C7	Energetic. Sociable. Politically concerned interests. *Dynamic*. Restless. Factual approach as opposed to interest in fantasy world.	Thorough. *Care for detail*. Extremely creative. Not concerned with social success. Gentle. Perceptive.	1	1	1	1	0	0	0	1	1	0	0	1
C8	Both need company. *Gregarious*. Prepared to compromise. Factual approach. Enjoy discussion.	Musical. Scientific but also keen on the 'unreal' world. *Fantastical*.	1	1	1	1	0	0	0	1	1	1	0	1

Figure 1. Jane's repertory grid.

another. Principal components analysis goes even further and assumes that the distances between points are themselves meaningful and that the distribution of points in space gives an indication of meaningful directions in that space. However, it is most often used just as a basis for clustering constructs according to their distance apart on the two principal dimensions so that the notion of the 'meaning' of these dimensions does not necessarily arise.

The grid of Fig. 1 was analysed using Slater's (1977) INGRID program for determining the principal components. Figure 2 shows the 12 elements and the two poles of each of the

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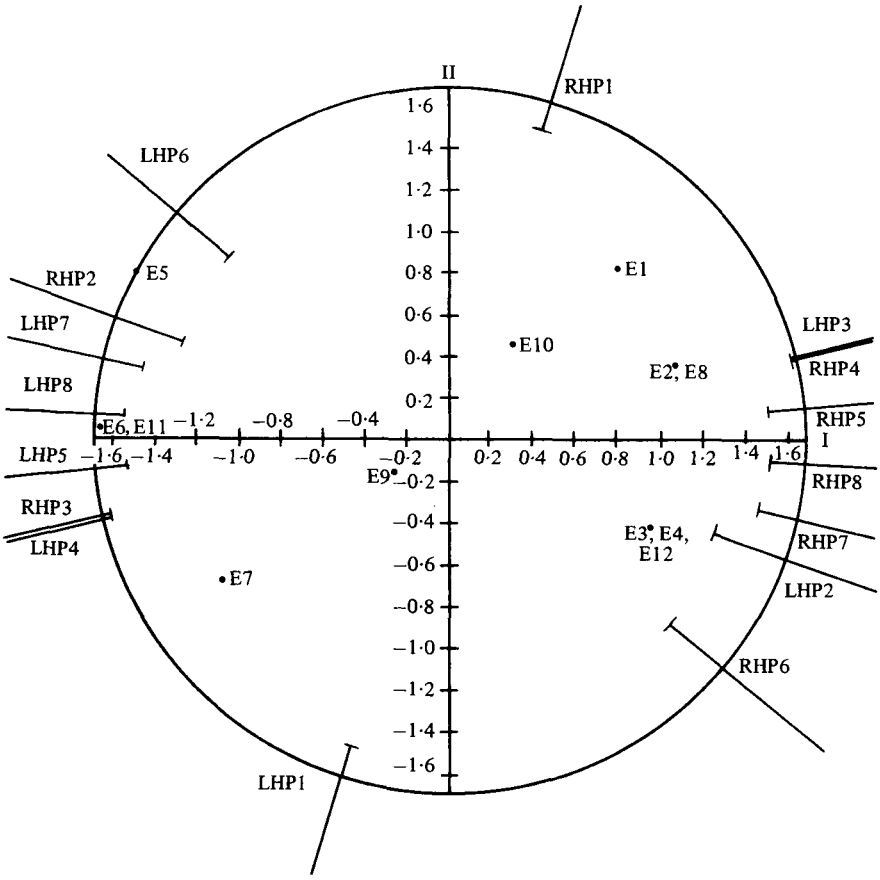

Figure 2. Principal components analysis of Jane's grid by INGRID.

eight constructs plotted against the first two principal components. In this section we will concentrate on the construct analysis and treat the element analysis later. It can be seen that the left-hand poles of constructs 4, 5, 7 and 8 form a fairly tight cluster together with the right-hand poles of constructs 2 and 3. The left-hand pole of construct 6 is associated more loosely with this but both poles of construct 1 are isolated well away from the cluster. There is a mirror image cluster of the right-hand poles of constructs 4, 5, 6, 7 and 8 together with the left-hand poles of constructs 2 and 3. Because the assignment of elements to poles is such that the vector of assignments to the left-hand pole is the reverse of that to the right-hand pole such a mirror image is bound to occur with conventionally elicited grids.

Atkin's (1974) *Q-Analysis* provides an alternative means of analysing the structure behind a matrix of data such as that of Fig. 1. In terms of the present discussion it is convenient to regard it as a form of hierarchical cluster analysis based on a distance measure, although it is conventionally presented in combinatorial topology terms. The data of Fig. 1 were analysed using a program QARMS (Q-Analysis of Relations in Multilevel Structures) that can also deal with grids using rating scales as well as the binary data shown. The results are shown in Fig. 3 with the connectivities also drawn out as a hierarchical cluster.

Shaw's (1980*a*) FOCUS algorithm is another distance-based grid analysis technique that

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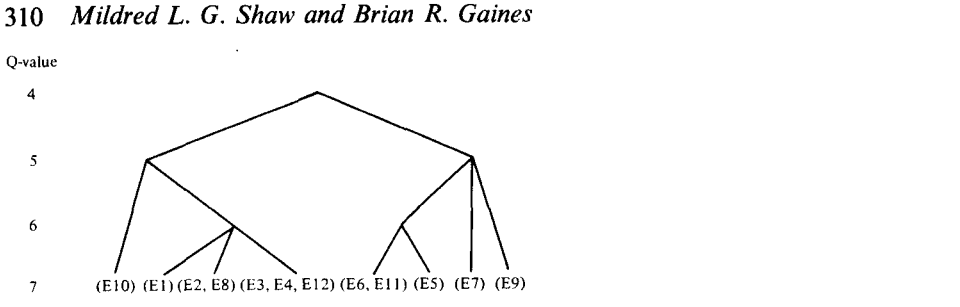

Figure 3. Q-analysis of Jane's grid by QARMS.

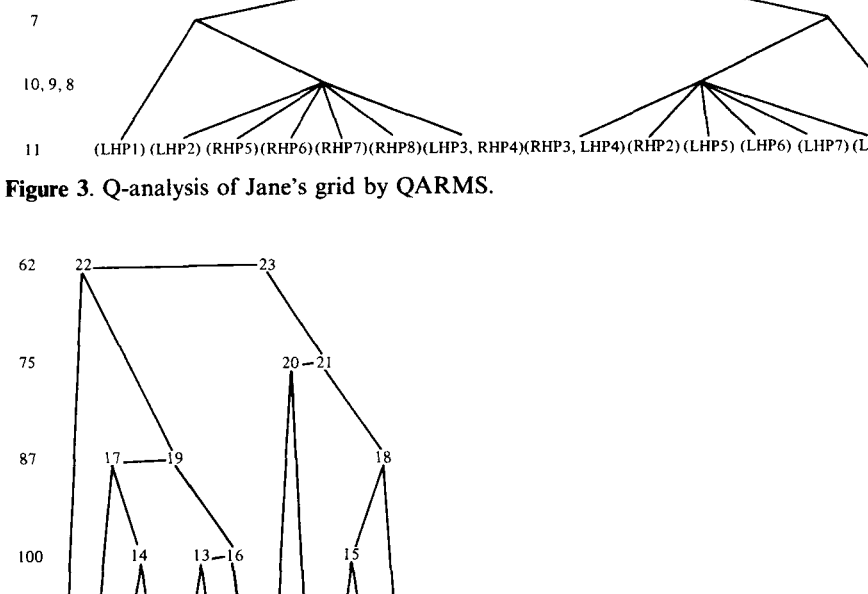

Figure 4. Cluster analysis of Jane's grid by FOCUS.

sorts the constructs into a linear order such that constructs closest together in the space are also closest together in the order. It has the advantage in presentation that the sorting is used only to re-present the original grid reorganized by the 'neighbourness' of constructs and elements. It is up to the user to construe meaning into the result and confirm this directly in terms of the original data. Figure 4 shows the grid of Fig. 1 as processed by

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FOCUS. Note that the letters 'X' and 'O' have been replaced by the numerals '1' and '2' respectively as the normal FOCUS convention, rather than the '1' and '0' used above. In reorganizing the grid FOCUS has also reversed constructs 2 and 3. Concentrating on the construct analysis again, it can be seen that constructs 3 and 4 are equivalent and close neighbours of 5, 7 and 8, and that this cluster is itself a close neighbour of the cluster formed by 2 and 6. Construct 1 is not linked into the other constructs at a meaningful level.

Thus, for this example at least, the actual clusters produced by FOCUS, QARMS and INGRID do not differ in any meaningful way. In general, since all these techniques use distance measures to produce clustered data, one would expect the results to be similar. The objective of FOCUS is not to produce a different analysis in terms of clusters but rather to present the analysis in terms of the data that produced it. In this way those who produced the grid are able to see how the decisions they made in doing this affect the actual analysis.

The *reversal* performed by FOCUS is an important operation in analysing a repertory grid. Kelly (1955, p. 283) uses such a process of reversal (which he calls 'reflection') in his analysis of repertory grids, and the need for it clearly arises from the artificiality of the assignment of 'left-hand' and 'right-hand' poles to a construct. Unless some special additional rationale is in operation, what are called the left-hand and right-hand poles of a construct may be reversed without distorting the grid providing the assignment of elements to those poles is also reversed. In principal components analysis and Q-analysis such reversals show up in the clustering of left-hand poles together with right-hand poles, for example as in Figs 2 and 3.

It is convenient to make a point here that applies to all techniques for grid analysis. Any relation we infer between constructs from a given grid are derived from a set of elements used in eliciting that grid. Hence they should be qualified by a reference to that set: not 'constructs 3 and 4 are equivalent', but rather 'in relation to elements 1 through 12, constructs 3 and 4 are equivalent'. To the extent that we drop this qualification we are proceeding inductively rather than deductively and our conclusions may be incorrect. This applies to any conclusion that extends the relation between constructs to elements that have not been tested, for example 'in relation to your close acquaintances, constructs 3 and 4 are equivalent'.

Therefore the various distance-based analyses of grids each provide related methods of clustering elements and constructs in such a way that one can provide feedback on possible *structures* underlying the construing. They have two factors in common that restrict their application in some contexts. Firstly, the structure exhibited is limited in its semantics to a symmetric relation of 'neighbourness' between the items clustered. Secondly, the analyses produce results about distances, components, connections, geometrical relationships, and so on, which represent a different way of looking at the data. This may be valuable in itself and may be expressed through basic notions of *similarity*. However, for some applications such as interactive discussion in conversational grid elicitation it would be preferable to have an analysis that expresses relations in the data in terms more immediately meaningful and directly related to the data itself. It was these considerations that led us to the logical data analysis described in the next section.

Grid analysis based on logical predicates

There is an alternative way of looking at the grid of Fig. 1 which views it not as a set of vectors in a space but instead as an assignment of *truth-values* to *logical predicates*. We may take the left-hand pole of each construct in Fig. 1 to be a logical predicate that may be applied to a person and take the assignment of the value to a particular element in the

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grid to mean that the predicate is *true* for that element. Conversely we may take the value of 0 assigned to an element for a construct to mean that the predicate represented by the left-hand pole of that construct is *false* for that element. It is convenient to use the abbreviation LHP*m* for the predicate that corresponds to the left-hand pole of construct *m*. Thus LHP5 is the predicate for the left-hand pole of construct 5, in this case 'enigmatic'. A repertory grid, such as that of Fig. 1, is then the matrix of such truth values for the *m* constructs and *n* elements involved.

Because of the inverse relation already noted between assignments to the opposite poles of a construct in a conventional repertory grid, the predicate corresponding to the right-hand pole is logically related to that corresponding to the left-hand pole. We normally require that an element be assigned to one, and only one pole, so that if LHP is true for some element then RHP must be false, and vice versa.

We have examined the logical propositions and derived a set of relations of equivalence and implication between the poles of constructs. (For details of the logical derivations see Gaines & Shaw, 1980.) The poles of two constructs may be quite distinct in terms of equivalence yet closely related in terms of entailment. For example, suppose that in construing people someone uses the two constructs *m*: runs–doesn't run and *n*: energetic–passive, then we might well expect to find that LHP*m* entails LHP*n* but that LHP*n* does not entail LHP*m*, that is that being a runner entails being energetic but being energetic does not entail being a runner. If we analyse such a construct structure in terms of distance measures and hence of equivalence only then we shall not derive such asymmetrical relations between constructs even though they are meaningful and of practical interest.

It is possible to derive the entailment structure between the poles of constructs. We only have to check the truth of the four possible implications for all elements. Thus LHP*m* entails LHP*n* is checked by noting whether whenever an element is assigned to the left-hand pole of *m* it is also assigned to the left-hand pole of *n*. If so, then the entailment relation holds true, otherwise it is false. Clearly, as we noted above, it would also suffice to check that whenever an element is not assigned to the left-hand pole of *n* it is also not assigned to the left-hand pole of *m*. We call the program that performs this analysis ENTAIL (Entailment Nets Through Analysing Implicational Links). Note again that the inference from a particular set of elements that one pole of construct *m* entails one pole of construct *n* is an inductive one if we assume that it applies to other elements in addition to those used in its derivation.

Figure 5 shows the entailments between the poles of the constructs derived by ENTAIL from the grid of Fig. 1 drawn out as a directed graph. There are effectively two main subgraphs which are mirror images of one another plus two isolated poles. One of the graphs shows the entailments for one set of poles, and the other the entailments for the opposite poles. Note that the 'reversal' of constructs 2 and 3 apparent in the INGRID, QARMS and FOCUS analyses shows up as LHP2 and LHP3 appearing in the graph of the right-hand poles of the other constructs and vice versa. Because of the essential bipolarity assumed in the elicitation of the grid the two graphs are essentially the same with the arrows and poles reversed in one relative to the other. In the next example we discuss extensions to the form of grids which would result in such pairs of graphs not necessarily having such a simple relation.

Note that we have taken advantage of the transitivity of the entailment relation not to draw in all the arrows strictly necessary. Thus we have not drawn an arrow from LHP2 to RHP7, RHP5, RHP4, and LHP3 because there is an arrow from LHP2 to RHP8 and then one from RHP8 to RHP7, RHP7 to RHP5, and so on. We can see from the figure that LHP2 entails RHP8, RHP7, RHP5, RHP4 and LHP3 by tracing through the graph. Note that the equivalence between LHP3 and RHP4 now shows up as mutual entailment.

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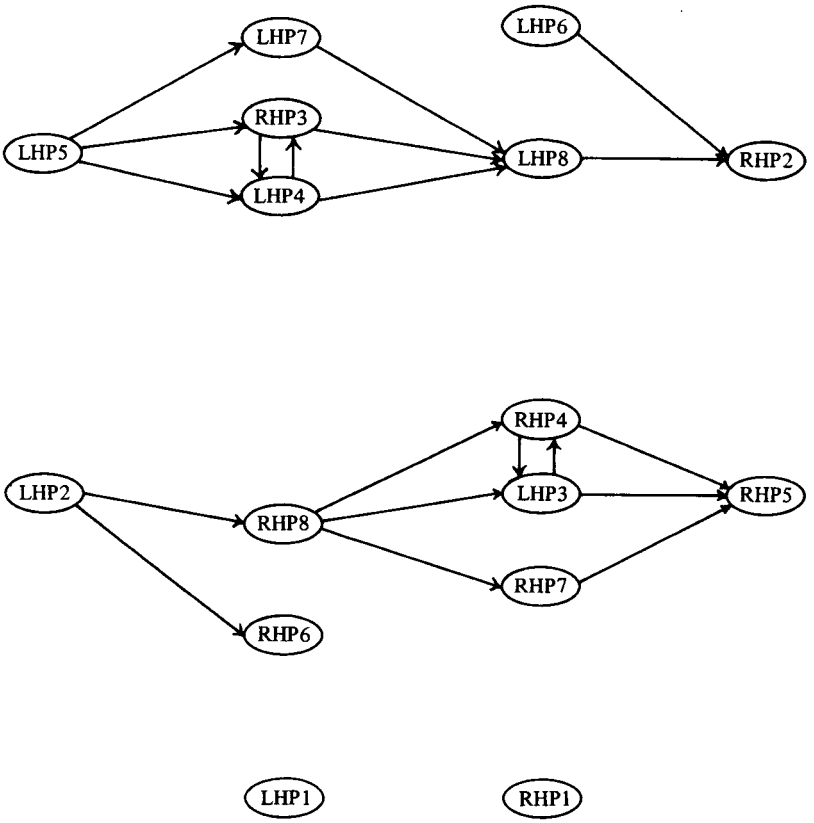

Figure 5. Entailment analysis of Jane's constructs by ENTAIL.

It is very interesting to compare Fig. 5 with the results of the INGRID clustering in Fig. 2 , the QARMS clustering in Fig. 3 and the FOCUS clustering in Fig. 4. We can see that the same hierarchy of clusters has turned up: (3,4); ((3,4),5,7,8); (2,6); (((3,4),5,7,8),(2,6)); with construct 1 unrelated to the others in all cases. Thus the ENTAIL analysis gives rise to the same basic clustering as did INGRID, QARMS and FOCUS. At a more fundamental technical level we would expect all such distance-based clustering techniques to show such similarity with reasonably structured data. Both the fundamental and empirical similarities are important in their own right since two of these programs are widely used for grid analysis and one would hope that any new technique would continue to provide at least the same basic analysis.

However, there is additional information in Fig. 5 that goes beyond that available in Figs 2, 3 and 4. This comes from the directed nature of the entailment links shown. There is equivalence only between LHP3 and RHP4–all the other relations are one-way only. To show the significance of this we have drawn out Fig. 6 which gives the full text attached by Jane to each pole of the construct together with the elements assigned to that pole. The asymmetry of the entailment relation may be seen by considering that from RHP4 to RHP5 for example. We see from the descriptions of the poles that Jane is saying that any one of her acquaintances who is *artistic*, and so on, is also *creative*, and so on. However, the converse does not hold.

From the element data in Fig. 6 we can see the reason for this asymmetry. For example, from the elements assigned to RHP4 and RHP5 we can see that the entailment between them not being mutual is due to Jane's acquaintance element 10 being termed *creative* but

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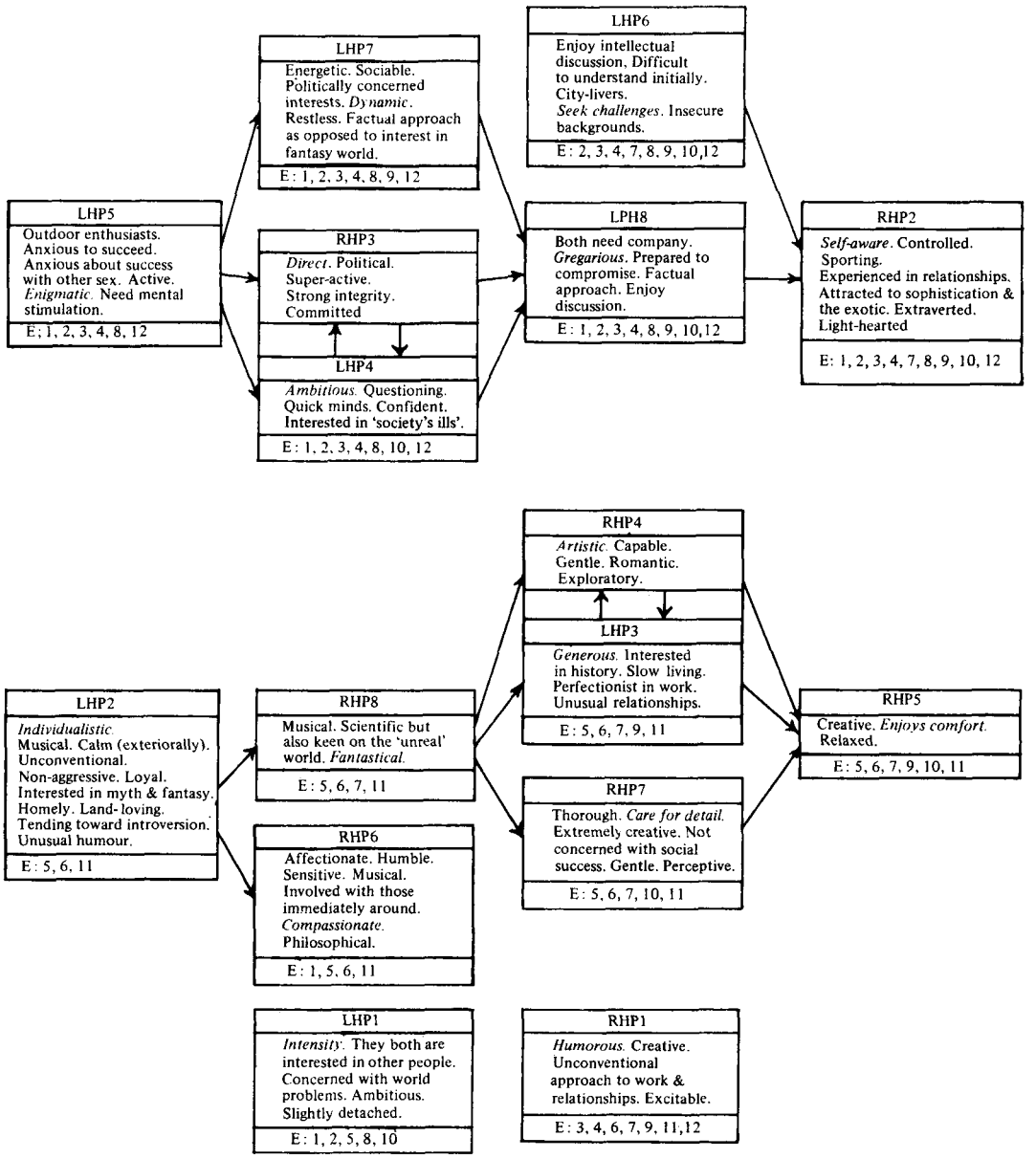

Figure 6. Entailment analysis of Jane's grid by ENTAIL.

not *artistic*. In this case only one element breaks down the equivalence. If we consider the entailment from LHP8 to LHP5, that her acquaintances who are *musical* are also *artistic*, then the converse is not true of two acquaintances, elements 9 and 10. And if we consider the entailment from LHP2 to RHP5, that being *individualistic* entails being *creative*, then the converse is not true for elements 7, 9 and 10. Thus the construct analysis produced by ENTAIL has reproduced the clusters shown by INGRID, QARMS and FOCUS but it has also shown up new features of the data not evident in these distance-based and essentially symmetric forms of analysis.

The element clusters that are exhibited in the other analyses also appear in Fig. 6.

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Looking first at the principal component analysis in Fig. 2, we can distinguish a cluster of elements on the left side comprising (5,(6,11)) with elements 7 and 9 not very far away; on the right side there is a fairly tight group of elements (1,(2,8),(3,4,12)) with 10 slightly closer to the centre. In the Q-analysis of Fig. 3 these clusters again appear (arbitrarily the other way round on the page), elements (1,(2,8),3,4,12) with 10 on the left and ((6,11),5) followed by 7 and 9 on the right. In the FOCUS analysis in Fig. 4 the main element clusters are (1,(2,8)),((4,3),12) with 10 next on the left, and (5,(6,11)) joining next to 7 and 9 on the right.

In Fig. 6 it can be seen from the lower half that the cluster of elements (5,6,11) connects to element 1 and element 7, then 7 links to 9 and 10. In the upper half the first cluster is (1,2,3,4,8,12) which is connected to 9 and 10 and then to 7. In Gaines & Shaw (1980) a more detailed logical element analysis is developed that applies when implications are interpreted as *preferences* for particular poles of constructs.

Thus the logical approach to grid analysis also leads to a comparable element analysis to other approaches. Note finally that the form of analysis produced by ENTAIL has some of the features of INGRID in that it is two-dimensional and some of the features of QARMS in that it provides hierarchic clusters. However, it also retains the key feature of FOCUS in that it re-presents the original data in a reorganized form. Like both INGRID and FOCUS it also shows the relation between elements and constructs, but unlike them it extends this relation to show the asymmetrical, directed entailment structure between constructs.

Extending entailment to rating scales

Kelly (1955) presented constructs as binary categories and based his own methodology for eliciting constructs on this. However, other workers found the need for 'shades of grey' between the two poles of a construct and in a later work Kelly notes that this is consistent with his notion of a construct:

> The construct, of itself, is the kind of contrast one perceives... while constructs do not represent or symbolize events, they do enable us to cope with events, which is a statement of a quite different order... They also enable us to put events into arrays or scales, if we wish (Kelly, 1970, pp. 13–14).

It is common in many practical applications of repertory grids to use an n-point scale with 1 being an assignment to the left-hand pole and n being an assignment to the right-hand pole, and intermediate numbers representing some form of 'intermediate' assignment; n is usually odd, 5 or 7, to allow a 'neutral' mid-point to the scale.

Methods of grid analysis based on distance measures apply readily to rating scale data if the scales themselves are assumed to form the axes of some coordinate system. Grid analysis based on logical predicates has been shown by Gaines & Shaw (1980) to extend naturally to rating scale data if the scales are assumed to represent truth values in a multi-valued logic (Rescher, 1969). In recent years such logics have been used by Zadeh (1965) to develop a theory of *fuzzy sets* that closely parallels that of classical set theory but allows for 'shades of grey' in set membership. He considers that elements of a set to take intermediate values of membership to the set and calls these values *degrees of membership* to the set. Since Zadeh's original study there has been a rapid growth in the literature on fuzzy sets and their application to system theory, medical diagnosis, psychological modelling, linguistics, and so on (Gaines & Kohout, 1977).

One important feature of Zadeh's work in the context of grid analysis has been its emphasis on the linguistic nature of human reasoning and the use of fuzzy set theory to model the use of *hedges* such as *very* and *rather* in human reasoning. This is similar to the

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                    * 1  2  3  4  5  6  7  8  9
                    ********************************
Involvement      1  * 4  3  2  1  5  1  2  3  1  Remoteness
                    *
Flexible         2  * 4  4  3  2  5  1  5  2  1  Rigid
                    *
Equipment        3  * 4  5  5  1  1  3  2  1  5  No equipment
                    *
Self-organized   4  * 5  4  4  3  5  1  2  2  1  Staff-organized
                    *
Small group      5  * 5  2  4  4  5  1  1  1  3  Large group
                    *
Variable content 6  * 4  4  2  3  5  1  5  5  1  Specific content
                    *
Like             7  * 5  4  2  2  5  1  5  5  1  Dislike
                    * * * * * * * * * * * * * * * * *
                      *  *  *  *  *  *  *  *  *  Informal interaction
                      *  *  *  *  *  *  *  *  Videotape
                      *  *  *  *  *  *  *  Programmed text
                      *  *  *  *  *  *  Library
                      *  *  *  *  *  Film
                      *  *  *  Practical
                      *  *  Seminar
                      *  Tutorial
                      Lecture
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Figure 7. Arthur's repertory grid.

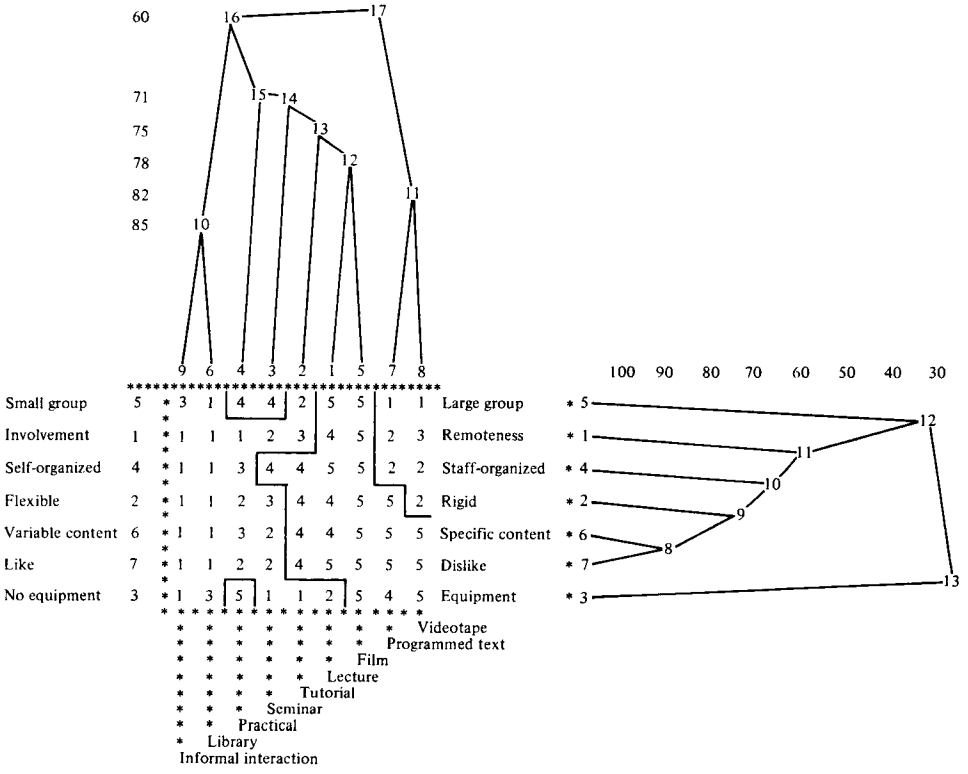

Figure 8. Cluster analysis of Arthur's grid by FOCUS.

interpretation of the points on a rating scale in terms of such hedges as *very*, *slightly* and *quite* used in semantic differential techniques (Osgood *et al.*, 1957). Thus there are natural verbal interpretations of the rating scale when values are input and these may also be applied to the equivalent values resulting from the ENTAIL analysis. One may say that there is a 'quite strong' or 'very strong' entailment from one pole to another. Our requirement that the terminology and concepts of the analysis be those of the data thus continues to be satisfied in the extension to multivalued logics.

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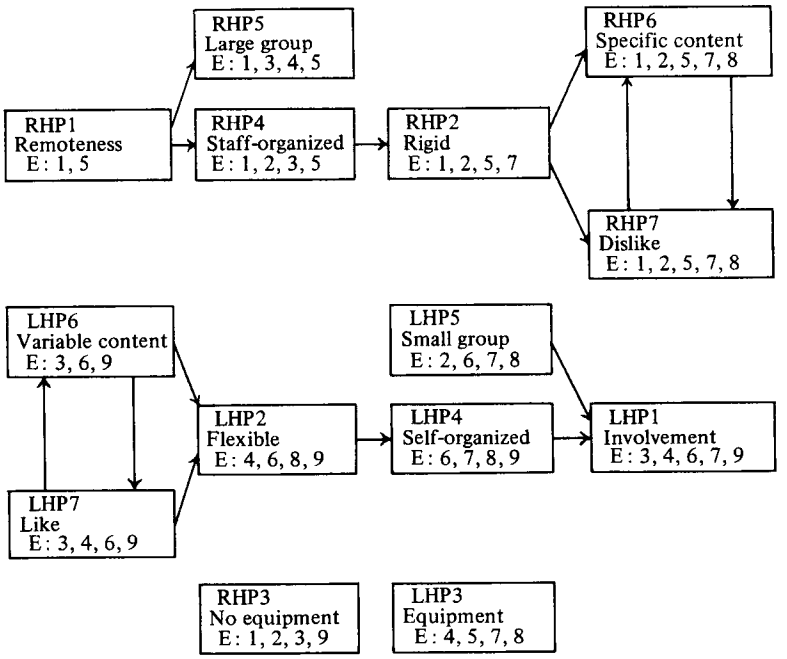

Figure 9. Entailment analysis of Arthur's grid by ENTAIL.

An approach to the grading of entailment has been given in Shaw & Gaines (1980) where we introduce the predicate *usually* in the analysis performed by ENTAIL. This predicate is a quantifier similar in nature to the 'for all' quantifier, but qualified to allow for some disconfirming instances so that it may be read as 'for all but *n* cases' where *n* is some small number such as 1 or 2. Such a quantifier allows a natural grading of entailment in terms that are immediately meaningful to the originator of the grid: 'when you say someone runs you always also say they are energetic' or 'when you say someone runs you usually also say they are energetic'. Use of the quantifier *usually* to give a graded analysis gives a structure similar to the connectivity levels coming from Atkin's Q-analysis. It is also readily extended to the multilevel case where rating scales rather than binary assignments are used in eliciting a grid.

The program ENTAIL has facilities for calculating entailments under the quantifier *usually*. If we apply it to Jane's grid then it condenses the construct structures shown in Fig. 5 into just: and equivalence between LHP2, LHP3, RHP4, RHP5, RHP6, RHP7 and RHP8; a similar equivalence between the opposite poles to these: LHP1, and RHP1. With more complex grids, however, we have found the use of graded entailment through such a predicate an important feature of the analysis.

ENTAIL has also been written to take into account such multivalued data (as have INGRID, QARMS, and FOCUS). Figure 7 is Arthur's grid using a five-point scale which is the result of a PEGASUS grid elicitation given in Shaw (1980*a*, p. 65). Figure 8 shows the FOCUSed version of this grid. It has then been reanalysed using ENTAIL with the quantifier 'usually' which will ignore the one case exception. The results are given in Fig. 9. Again, there is a close correspondence between the construct clusters. FOCUS shows the hierarchy of (((((6,7),2),4),1),5) with 3 joining more remotely; ENTAIL shows a similar cluster of (((6,7),2),4) joining next with 5 and then incorporating 1; 3 is unrelated to the other constructs. The main element clusters shown by FOCUS are ((((5,1),2),3),4), (7,8),

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and (6,9). The clusters exhibited by ENTAIL are ((1,5),2,3,4) with (7,8) joining later shown in the top half of the figure, then in the bottom half the (6,9) group is central to all the clusters.

It seems, therefore, from the two examples given that ENTAIL picks up any clustering exhibited by the existing distance-based methods of grid analysis in both the constructs and the elements. ENTAIL is equally applicable to the rating scale grid data as the binary grid data.

Conclusion

In this paper we have shown the similarities in the resulting clusters of constructs and elements produced by the variety of commonly used distance-based grid analysis programs. We have suggested that a repertory grid may be regarded as a logical structure in which the poles of constructs are predicates applying to the elements, and how this type of analysis can be used to obtain asymmetric relations between elements and between construct poles such as that of implication. We have given examples of such analysis produced by the computer program ENTAIL both with binary and multipoint rating grids, and illustrated that the results both reflect those of previously used methods and go beyond them in producing a set of hierarchies or relationships of implication.

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