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APPEARANCE AND REALITY: IS THE BIG FIVE THE STRUCTURE OF TRAIT DESCRIPTORS?

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Summary—It is argued that contrary to the claims of Big Five investigators, the structure of trait descriptors is still very much an open issue. This is because their methodology, factor/component analysis paired with the dimensional interpretation/simple structure (DISS) procedure, does not investigate the closed topological manifold that constitutes the 'structure' of a set of variables. Instead, radex-related configurations are likely candidates for the structure of trait descriptors. Some preliminary support for this claim is given by an analysis of the NEO Personality Inventory (NEO-PI) (Costa & McCrae, *Manual for the NEO PI-R*. Odessa, FL: Psychological Assessment Resources, 1992), a Big Five questionnaire measure, and the Goldberg-40 (Goldberg, *Review of Personality and Social Psychology*, Vol. 2, pp. 141–165, 1981. Beverly Hills, CA: Sage), an adjective measure. In particular, the NEO-PI and Goldberg-40 are shown to have radex structures. A facet theory (Guttman, *Psychometrika, 36*, 329–346, 1971) rationale is provided for these findings. © 1997 Elsevier Science Ltd

INTRODUCTION

From many quarters of psychology the refrain can now be clearly heard: The Big Five, or five-factor model (FFM), is the correct description of trait descriptors. The Big Five is said to be a discovery of significant stature, both replicable and generalizable. It places personality research "on the brink of a solution to a scientific problem whose roots extend back at least to Aristotle" (Goldberg, 1993, p. 26), the problem of a scientifically compelling structural representation of personality descriptors. Indeed, from the so-called lexical hypothesis, "That the most important individual differences in human transactions will come to be encoded as single terms in some or all of the world's languages" (Goldberg, 1993, p. 26), to the early factor analytic studies of Cattell (1943), Fiske (1949), Tupes and Christal (1958, 1961), and Norman (1963), and finally to the recent work of Goldberg (1990, 1992), Digman (1990), McCrae and Costa (1985, 1987, 1989a), and many others, the results seem to point to the same conclusion: That 'Extraversion', 'Agreeableness', 'Conscientiousness', 'Emotional Stability', and 'Culture', or close variants of these, are the fundamental dimensions of Personality. The received view is that researchers during the 1980s

> "were led to conclude that these factors were fundamental dimensions of personality, found in self-reports and ratings, in natural languages and theoretically based questionnaires, in children, college students, and older students, in men and women, and in English, Dutch, German, and Japanese samples". (John, 1990). "All five factors were shown to have convergent and discriminant validity across instruments and observers, and to endure across decades in adults ..." (McCrae & John, 1992, p. 176).

On a similar note,

> "The five-factor model was identified originally in factor analyses of trait attributions procured from peer observers ... Subsequent replications have demonstrated that this structure is robust for peer and self-ratings of adjective descriptors using multipoint rating formulas ... Recent work suggests that these same factors can be extracted from self-reports and peer ratings of the item phrases contained in standard personality inventories ..." (Briggs, 1992, p. 256).

Hence, with overwhelming evidence in favour of the Big Five structure, the modern personality researcher may safely assume that it is

> "... more fruitful to adopt the working hypothesis that the five-factor model (FFM) of personality is essentially correct in its representation of the structure of traits and to proceed

> to its implications for personality theory and its applications throughout psychology" (McCrae & John, 1992, p. 176).

More forcefully, one may conclude that:

> "A series of studies of personality traits has led to a finding consistent enough to approach the status of law. The finding is this: If a large number of rating scales is used and if the scope of the scales is very broad, the domain of personality descriptors is almost completely accounted for by five robust factors" (Digman & Inouye, 1986, p. 116).

Even on a more cautious note, one may still conclude that:

> "After more than five decades of dedicated research into how individuals describe themselves and others, the five-factor model for describing the universe of personality trait descriptors enjoys a substantial lead over its primary competitors" (Briggs, 1992, p. 254).

Yet despite this 'emerging consensus' in personality research, there exist important reasons for doubting that the Big Five constitutes the appropriate description of the empirical structure of trait terms. Of course, the issue of the correctness of the Big Five claim is of fundamental importance, since, prior to explanation, science requires accurate representations of that which is to be explained. Science prior to Copernicus, for example, had to explain 'facts' that were congruent with a model of space that depicted the sun as revolving around the earth. To provide substance to this scepticism about the Big Five, a number of fundamental principles from psychometrics must be recalled. The next section provides this grounding. It should be emphasized that this article will not address the controversial issue as to whether, in the first place, the variables considered in Big Five research should be viewed as comprising the domain of personality descriptors. Neither is the current work a general critique of the usefulness of the Big Five as a model. Instead, the present work addresses the narrower issue of the correctness of the Big Five claim about the empirical structure of the variables that *are* in actuality studied by Big Five researchers.

STRUCTURE AND REPRESENTATION

The issue on which this paper centres is, generally speaking, the empirical structure of a set of variables, and, in particular, the Big Five claim about the structure of trait terms. However, the coherent treatment of this issue first requires a clarification of three related concepts: structure, representation, and mode of representation. In the first place, the investigator must specify the domain of variables on which the investigation will focus. Given such a specification, an investigation of the empirical 'structure' of n variables drawn from the domain may be undertaken. In practice N subjects receive scores on the variables according to some numerical assignment procedure. The variables may then be conceptualized as points in N-dimensional Euclidean space, the coordinates of each variable given by the N subject scores on that variable. The 'structure' of the variables, of maximum dimensionality n ($n \leqslant N$), is the point manifold defined by these n points (see e.g. Holland, 1990; Krzanowski, 1988; McDonald & Swaminathan, 1972). Measures of the 'relatedness' or 'proximity' of the variables (e.g. their correlations) are functions of the distances between the variables that comprise the structure. The structure itself, however, has a 'shape' or topology. Important features include distinctive clumpings of the variables (including the special case of clumps that are orthogonal to each other), hollow or empty areas (where no variables are to be found), and, of special importance, topological features implied by psychological theory (e.g. specific orderings of the variables). In practice one does not study the structure of the variables *per se*, because, for any study with a reasonable sample size, the structure is embedded in a space of far too high a dimensionality. As a result, a low dimensional approximation or 'representation' of the structure becomes the focus of investigation. In psychology, approaches to low dimensional representation usually involve the application of a data analytic technique to a matrix of pairwise coefficients of association (e.g. as in the factor analysis of a matrix of correlations). An adequate representation is one that retains the important features of the structure of the variables (i.e. in which the loss of information is not too great). Hence, a 'correct' description of the structure of the variables is, for all intents, equivalent to an 'accurate' description of the structural features of an

'adequate' representation. The point is that an investigator who claims that the structure of personality descriptors is ' ... ', is actually making two claims: (1) That he or she has generated an adequate representation of the structure; and (2) that he or she has provided an adequate description of the representation. Importantly, the 'mode of representation' (association coefficient plus data analytic technique) chosen, places non-trivial restrictions on the conclusions that can be made about the empirical structure of a set of variables. To put this another way, the mode of representation becomes, to some extent, intertwined with what is being represented. A classical example of 'misrepresentation' can occur when linear factor analysis is applied to a matrix of ϕ coefficients among unidimensional, Guttman scalable items (see e.g. Gorsuch, 1983; McDonald & Ahlawat, 1974). If no two items have the same mean, the matrix will be full rank. The misrepresentation will be especially pronounced when, in addition, the means of the items are extreme since the best linear approximation to a non-linear regression depends on the region in which the data are most dense, i.e. in the region of the item means (Mislevy, 1986). It is therefore imperative that the investigator understand the properties of the mode of representation being considered, so that a sound choice can be made in this regard. It is also essential in the consideration of empirical results from personality research that the mode of representation employed be carefully scrutinized.

THE BIG FIVE RESULT

Wiggins (1973, p. 338) provides a rough, straight-forward account of the research paradigm that underlies the Big Five result:

> "First, a procedure is developed for systematic sampling of the potential universe of trait descriptors contained in ordinary language. Second, by means of both rational and empirical procedures, the initial list of terms is reduced to a more manageable set. Third, the apparent trait attributes involved are represented by bipolar rating scales ('talkative versus silent'). In a population of *S*s, known to each other, these scales are administered in the form of peer ratings that require each *S* to evaluate some or all of his peers with respect to the attributes. The intercorrelations among rating scales are used as a basis for determining underlying dimensions by means of factor analysis."

Of chief interest to the present work is that factor, or principal component, analysis is the technique of choice among Big Five researchers. To review, basic output from a factor analysis is a set of np factor loadings. These loadings provide the locations in the p-dimensional common factor (solution) space, of the n variables analysed. The n variables located as such also comprise a point manifold, but this point manifold (located in a p-dimensional embedding space) is the factor analytic 'representation' of the 'structure' of the variables (which is located in an N-dimensional embedding space). In this work, so long as the context is clear, both the true 'structure' of the variables and the 'representation' of the structure will be called simply, the structure.

With regard to the employment of factor analysis in Big Five research, Wiggins' account requires the following augmentation. First, the positions of the common factor axes in the p-dimensional common factor space are often fixed *post hoc* by maximizing a quantitative criterion (e.g. a varimax or promax criterion). However, whether the factor axes are orthogonal or oblique is, in general, of little importance, for factor axes are merely reference axes for the common factor space, and say nothing about the 'structure' itself. It is a common mistake of researchers to conflate the characteristics of the common factor (embedding) space (i.e. the orientation and number of reference axes) with the structure itself (see Borg & Lingoes, 1989). The only thing required of a set of reference axes is that they provide a means to 'reliably' locate points. As stated by Schlesinger and Guttman (1969, p. 96):

> "The notion of coordinates is subsidiary (and often irrelevant) to the notions of configurations or laws of formation of points in the space."

Second, the pair of Dimensional Interpretation and Simple Structure (DISS) (see Borg & Lingoes, 1989) is employed as an interpretative device. In the simple structure procedure, one considers only those factor loadings of a magnitude greater than 0.3, or perhaps 0.4, in absolute value. Clearly,

the simple structure 'procedure' is to be distinguished from both the concept of 'rotation to simple structure' (see e.g. Cureton & D'Agostino, 1983) and the 'criterion' of simple structure. The simple structure procedure involves neither a rotation of the factor axes to an optimal orientation, nor an assessment of whether the factor analytic representation is describable as orthogonally related subsets of variables. In the dimensional interpretation procedure, one examines the structure of the variables (in the common factor space) by considering the projections of the variables onto the factor axes one axis at a time. The idea is that one examines the first dimension, and based on the loadings of the variables on this dimension, one 'names' the dimension. One then proceeds to subsequent dimensions and repeats this process. Examples of the DISS procedure can be found on page 347 of Wiggins (1973), and throughout the Big Five literature (e.g. McCrae & Costa, 1985, p. 715, p. 719). Even when small loadings are presented in the results sections of Big Five studies they are effectively ignored when the results are discussed and summarized. Factor analysis paired with the DISS procedure, and often with an initial varimax rotation, is the mode of representation that is at the heart of the Big Five library of results. Given this mode of representation, what is the Big Five claim? To say that trait descriptors are five-dimensional is not to speak of their 'structure', but only the dimensionality of the factor analytic embedding space. The Big Five claim is more particular than this: It is that the 'structure' itself is five-dimensional *and* orthogonal, with the orthogonal sets of variables organized under the labels 'Extraversion', 'Agreeableness', 'Conscientiousness', 'Emotional Stability', and 'Culture'.

APPEARANCE AND REALITY

> "For instance, the Roman astronomers had to be convinced that the things that they saw through the telescope were not optical illusions produced by the instrument... Furthermore, the whole question of the relation of sensory experience, aided by instruments to 'reality' is by no means simple, and Galileo meditated deeply on the problem" (Segre, 1969, p. 20).

It is argued here that, in contrast to the claims of the Big Five literature, no evidence has as yet been presented to support the claim that the structure of trait descriptors is five-dimensional and orthogonal. This assertion may seem far-fetched, but only until it is realized that Big-Five investigators have simply not examined the structure of their variables. This state-of-affairs can be blamed on their adoption of a completely inadequate mode of representation: Factor analysis paired with the DISS procedure.

The DISS procedure

The choice of the DISS procedure is a crucial error. To understand why, it must be remembered what constitutes the empirical structure of a set of variables. When factor analysis is the tool of representation, it provides coordinates (factor loadings) that locate the variables as points in the p-dimensional common factor space. These points, considered jointly, constitute the 'structure' that is of interest. The investigator engaged in a structural analysis must examine this structure and describe its characteristic topology, i.e. important regional clumps of variables, empty spaces, etc. The DISS procedure, on the other hand, ensures a systematic 'misrepresentation' of the structure. First, it is simply not possible to gain an understanding of the topology of a p-dimensional point manifold by considering the projections of the variables on each dimension, one dimension at a time. The structure must be examined as a whole. This is precisely why Thurstone was in the habit of creating three dimensional models to display factor analytic representations of his variables (see Schlesinger & Guttman, 1969, for further commentary on this issue). Second, the practice of ignoring small to moderate factor loadings is equivalent to inexplicably ignoring features of the structure itself. The mistake is to view a loading of, for example, 0.05, as 'unimportant'. A small loading, however, is no less important than a large loading, for, just like a large loading, it is 'required' to position a variable in the common factor space. The variables positioned in the common factor space constitute the structure, and the structure is the focus of investigation. Every loading is required to generate the factor analytic representation of the structure. Far from being a rational aid to interpretation, the DISS procedure militates against the aims of research into the structure of a set of variables. To put this more bluntly, results generated on the basis of the DISS procedure

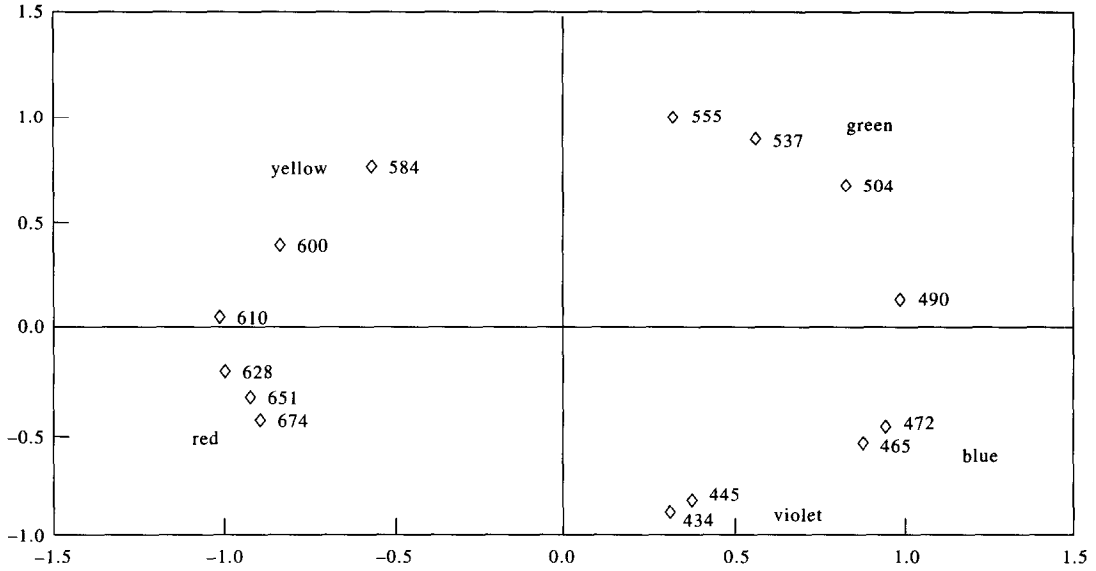

Fig. 1. NMDS of Ekman's 14 spectral hues.

do not address the issue of the structure of a set of variables. Moreover, the DISS procedure is in no way a necessary accompaniment to factor analysis, and in many ways is contrary to the aim of factor analytic representation. Hence, the Big Five claim that the structure of trait descriptors is five-dimensional and orthogonal is not supported by the research, which, to this point, has not examined the structure of these variables. The structure of trait descriptors is still very much an issue.

Figure 1 is a representation of the structure of the judged similarities of colour samples for 14 spectral hues (Shepard, 1978).

The structure depicted is known as a circumplex (Guttman, 1955), a particular circular arrangement of variables. Colour samples that are perceptually more similar are close together in the representation, while those that are dissimilar are farther apart. The variables "go in a circle" because "hues at the two ends of the visible range of wavelengths, red and violet, are perceptually more similar to each other than either is to intermediate wavelengths such as green" (Shepard, 1978, p. 39). No two hues are very much more dissimilar than the rest, resulting in pairs of roughly the same degree of dissimilarity (e.g. 584 and 472; 651 and 504; 610 and 490). The circumplex pictured is for colour samples with the same degree of saturation. If saturation were to be changed, then the diameter of the circumplex would change. This is because samples of low saturation tend to look similar regardless of their hue (and so result in a circumplex with a small diameter about the origin). The point then is that the structure as a whole, both the hollow middle region and the positioning of the variables around the perimeter, is 'fundamental' to the scientific explanation of colour perception. What is important is the 'overall' spatial organization of the variables, hence the term circumplex to designate the structure as a whole. As Shepard states of the circumplex of Fig. 1, "the underlying structure is really one-dimensional, as we should expect from the fact that the colours differed with respect to the single physical variable of wavelength" (Shepard, 1978, p. 38). Presented in Table 1 is a summary of the circumplex result after application of the DISS procedure (with a 0.4 cut-off).

Notice what is lost in the use of the DISS procedure. The circularity of the structure is no longer apparent from the results. Nor is the empty centre that is definitive of the circumplex. In fact, it is not possible to describe a circumplex by considering one dimension at a time. Notice also that science, in the wake of the DISS procedure, has little to explain with regard to the role of hue and saturation (and especially their interaction) in governing colour perception.

Percent of structure ignored

To this point it has been shown that results generated on the basis of the DISS procedure have little, if anything, to do with a correct account of the structure of a set of variables. But Big Five

Table 1. DISS representation of colour circumplex*

Hue**	Dimension 1	Dimension 2
434		−0.897
445		−0.848
465	0.880	−0.563
472	0.943	−0.511
490	0.987	
504	0.831	0.649
517	0.564	0.868
555		0.981
584	−0.560	0.757
600	−0.831	
610	−1.01	
628	−0.999	
651	−0.926	
674	−0.892	−0.445

Note: Coordinates less than 0.40 omitted. * output not meant to depict the factor analysis of a correlation matrix. ** Hue in millimicrons.

results are generated by precisely this procedure, and so cannot be taken as informative of the structure of trait descriptors. However, what is missing is an indication of the extent of damage induced by the DISS procedure in the Big Five context. There are a number of ways to examine this issue, the most satisfactory being a comparison of the Big Five result to the findings from a reasonable structural analysis. Steps will be taken towards this end later in this paper. For the moment, a slightly different approach will be taken. Since the *pq* loadings of a factor analysis constitute the representation of the structure, it follows that when certain loadings are ignored, a certain percentage of the common factor, or 'structure related', sum of squares (i.e. sum of squared factor loadings) is ignored. Hence, one may compute, for several Big Five studies, the percentage of structure related sum of squares ignored in the employment of the DISS procedure. Using a 0.4 cut-off for the loadings, we find that the figure is 16.2% in Norman (1963), 16.3% in Piedmont, McCrae and Costa (1991), 32% (varimax rotation) and 30% (validimax rotation) in McCrae and Costa (1989b), and 26.6% in Costa and McCrae (1992, p. 44). These figures are very large when one recalls that they correspond to a component of the sum of squares associated with the structure itself, 'after' the variables have been 'purified' of measurement error. Thus while the damage seems insignificant when loadings are considered one at a time, the cumulative loss of information about the structure is often sizable.

It might seem, on the other hand, that at least the simple structure procedure can be justified according to the following argument: While admittedly, small loadings are ignored, this is because the 'pattern' of the small loadings has not, in the past, replicated over studies. Small loadings arise from measurement error and therefore should be disregarded. This view, however, is misguided. What is of interest is the 'structure', the point manifold embedded in a *p*-dimensional common factor space. Even small rotations of the reference axes can make the set of *pq* loadings, especially the smaller loadings, change, while the structure itself remains the same. To put this differently, it is not the projections *per se* that are of interest, but the structure as a whole. The same structure can be associated with markedly different sets of loadings. More will be said on this issue in the next section.

Robustness of the irrelevant variety

Much is made of the supposed robustness of the Big Five result. Indeed the result has been obtained in a great many contexts and over a significant span of time. Hence, it would be rather silly to argue the robustness claim. However, the employment of the DISS procedure means that whatever is being shown to be robust, it is certainly not the structure of trait descriptors. The DISS procedure systematically ignores features of the structure (e.g. the regional topology of the variables), and, of course, robustness is always possible if enough detail is ignored: The world's oceans look much the same when viewed from a helicopter 1000 feet above the surface. To make matters more

Table 2. Coordinates from Biggest Two studies

Variable	Dimension 1	2	Variable	Dimension 1	2
(a)					
1			13		
2			14		
3			15		
4		0.40	16		−0.40
5		0.50	17		−0.50
6		0.60	18		−0.60
7			19		
8			20		
9			21		
10	0.40		22	−0.40	
11	0.50		23	−0.50	
12	0.60		24	−0.60	
(b)					
1			13		
2			14		
3			15		
4		0.45	16		−0.45
5		0.44	17		−0.44
6		0.50	18		−0.50
7			19		
8			20		
9			21		
10	0.45		22	−0.45	
11	0.44		23	−0.44	
12	0.50		24	−0.50	

Note: Coordinates less than 0.40 omitted.

concrete, consider the following scenario. Researcher 1 analyses a set of personality variables and obtains the coordinates shown in Table 2a.

After applying the DISS procedure she declares dimension 1 to be defined by variables 1–4, and dimension 2 to be defined by variables 5–8. She calls this structure the 'Biggest Two'. A second researcher analyses the same set of variables and obtains the coordinates shown in Table 2b. After applying the DISS procedure he likewise declares dimension 1 to be defined by variables 1–4 and dimension 2 to be defined by variables 5–8. After consulting the literature, he states that his results are a replication of the 'Biggest Two' result. However, as illustrated in Fig. 2, the structures from the two studies are, in fact, very dissimilar.

The structure of researcher 1's variables (Fig. 2a) can be described as two orthogonal sets of variables, while researcher 2's variables (Fig. 2b) constitute a single circumplex-like structure. The appearance of robustness is the result of an improper grasp of structure: The 'Biggest Two' is not the structure of the variables in either study. Each investigator, in employing the DISS procedure, arrived at an erroneous conclusion. Now the situation in Big Five research is vastly more complex, since the structure of the variables is arguably embedded in a five-dimensional space. Hence, the DISS procedure is that much more likely to lead to an erroneous characterization of structure, and an irrelevant robustness.

Dimensionality and factor analysis

At this point it should be emphasized that the flaw in the Big Five strategy lies not with the use of factor analysis *per se*, but instead with the use of the DISS procedure. Employment of the DISS procedure will often result in a 'misread' of the p-dimensional structural representation provided by factor analysis. However, even if the DISS procedure was discarded, difficulties would still remain in coming to an understanding of the structure of trait terms. For there would still be the necessity of grasping the topology of a structure that is embedded in a p-dimensional space. If, for example, p is five, then it is no easy matter to get a sense of the structure as a whole. Typically one would have to go about this task by examining a number of two- and three-dimensional projections of the structure. On this note, personality researchers may not realize that factor analysis as a tool of representation is a very particular choice. It involves a 'linear' mapping of proximity measure (e.g. correlation) into distance (i.e. the distances implied by the positions of the variables in the p-

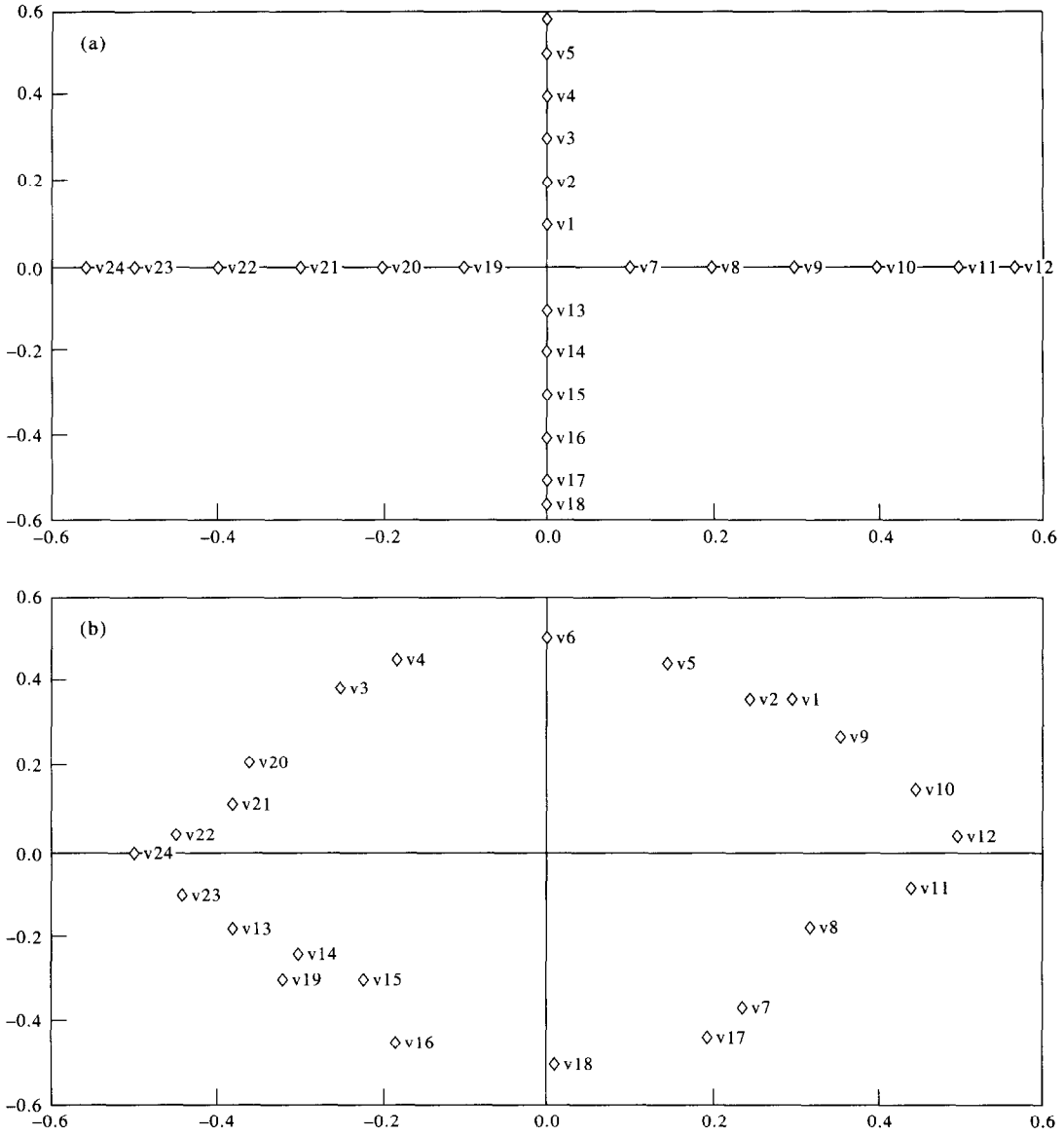

Fig. 2. Representations from Biggest Two studies.

dimensional common factor space). Whether such a mapping is appropriate or useful is a question of great importance. What should be made clear is that techniques like non-metric multidimensional scaling (NMDS) do not insist on a linear mapping. NMDS merely seeks a 'monotone' mapping, so that smaller distances in the solution space are associated with larger input proximities. The importance of this lies in the fact that NMDS will typically require a solution space of smaller dimensionality than factor analysis, making it easier to detect important topological features of the structure (see e.g. Schlesinger & Guttman, 1969).

Guttman and his colleagues (Borg, 1981; Shye, 1993) provide examples of the structural laws that have been discovered with the aid of NMDS and related techniques. In fact, Fig. 1 was generated by the application of NMDS to Ekman's similarity data (Ekman, 1954). Interestingly, the data were originally factor analysed (Ekman, 1954). Table 3 presents the varimax rotated loadings from a factor analysis of the data.

The data appears to be five-dimensional (using a simple roots greater than one criterion). To say the least, the circumplicial structure of the data is no longer obvious in the factor analytic results.

Table 3. Varimax rotated loadings from factor analysis of 14 spectral hues

Hue*	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
434	0.099	0.029	0.194	0.923	0.007
445	0.086	0.043	0.252	0.913	0.008
465	−0.021	−0.023	0.817	0.365	0.049
472	−0.019	0.014	0.866	0.301	0.029
490	0.040	0.409	0.767	−0.051	−0.055
504	0.059	0.767	0.382	−0.105	−0.051
517	−0.005	0.906	0.029	0.065	0.096
555	−0.047	0.835	−0.029	0.093	0.234
584	0.090	0.213	−0.002	0.007	0.823
600	0.355	0.057	0.016	−0.003	0.841
610	0.701	−0.039	0.032	−0.008	0.554
628	0.900	−0.007	0.001	0.035	0.245
651	0.928	0.010	0.010	0.061	0.097
674	0.862	0.016	−0.017	0.107	0.035

Note: * Hue in millimicrons.

In fact, the 'orthogonality' of clumps of variables appears every bit as compelling as for the Big Five result. Yet, as Shepard (1978, p. 40) states

> "Far from requiring the five dimensions of Ekman's own factor analytic representation, some 99% of the variance of the data could be accounted for by just two spatial dimensions."

Furthermore,

> "Despite his own theory, Ekman's data thus conform with the view, long ago set forth by Isaac Newton" (see Herrnstein & Boring, 1966, p. 11), "that the proper perceptual representation of spectral hues is on a 'colour circle'" (Shepard, 1978, p. 39).

Once again, the explanations and theories of science depend very heavily on accurate representation.

A DIFFERENT CONCLUSION—THE RADEX

To this point it has been argued that the structure of trait descriptors is very much an open issue due to the absence of a true investigation of 'structure'. Nothing, however, has been said about what the structure of trait descriptors 'might' in fact be. In the present study the aim is to make some preliminary inroads with respect to this issue. In particular, NMDS is used to examine the structures of the NEO personality inventory (NEO-PI; Costa & McCrae, 1992), and the Goldberg-40 (1981). The NEO-PI is an inventory comprised of 30 facet scales, six for each of the five constructs of the Big Five. Its psychometric properties are quite satisfactory, and in a series of studies McCrae and Costa (e.g. 1987, 1989a, Costa & McCrae, 1992) claim to have: (1) shown that the structure of the NEO-PI is in agreement with the Big Five result; (2) used the NEO-PI as a framework for integrating a wide variety of other questionnaire and rating scales within the Big Five scheme. The Goldberg-40 is a set of 40 bipolar adjective scales, eight scales designed to mark each of the Big Five dimension. While an analysis of the NEO-PI and Goldberg-40 by no means settles the question of the structure of trait descriptors, it should at least be highly instructive, especially since both have been found to have structures that accord with the Big Five result when the illegitimate DISS procedure is used.

STUDY 1

Method

The NEO-PI data was the correlation matrix among the 30 NEO-PI facet scales found in Costa and McCrae (1992, p. 100–101). Non-metric multidimensional scaling (primary approach to ties, Kruskal's monotone regression) was applied to this correlation matrix.

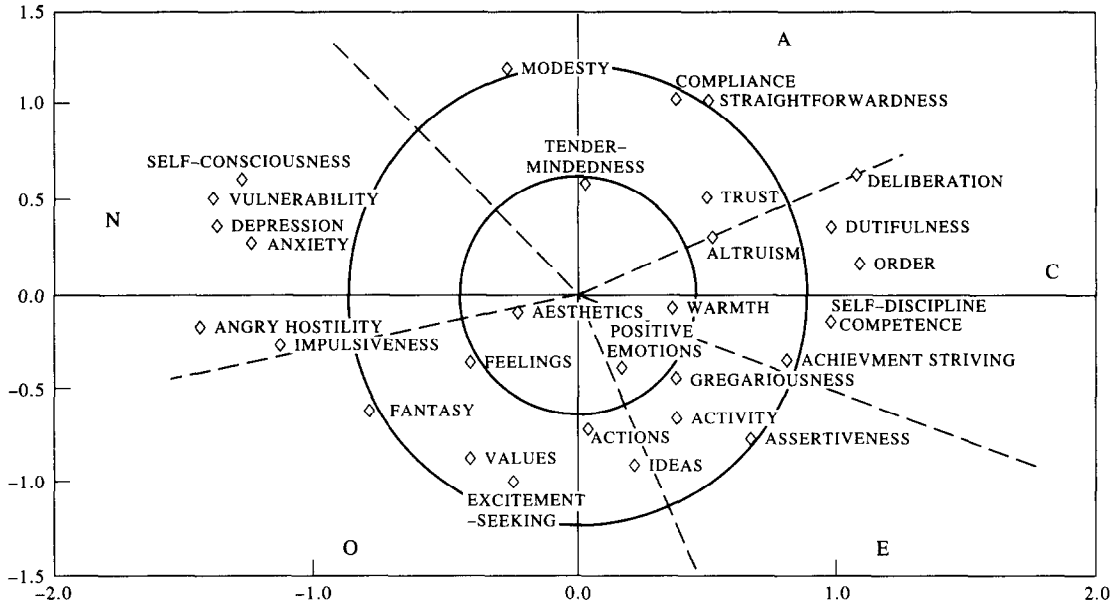

Fig. 3. Two-dimensional NMDS for NEO-PI facet scales.

Results

Figure 3 depicts the NMDS representation of the 30 facet scales of the NEO-PI.

In the first place, only 'two' dimensions were required to adequately summarize the relations among the variables (stress = 0.14), while a factor analysis requires at least five dimensions. Hence, the structure of the NEO-PI facet scales can be easily visualized in the NMDS representation. What is there to be seen? The empirical structure exhibited in Fig. 3 is known as a radex (Guttman, 1957; Shye, 1978). To get a sense of the features that comprise a radex, first notice that each of the five sets of facet scales are contained within a distinct conical region, and that these regions share a common origin. Second, there is a partial or 'circular' ordering of the five conical regions themselves, beginning with Neuroticism, and moving in a clockwise direction through Agreeableness, Conscientiousness, Extraversion, and Openness. The ordering is partial because it has no beginning and no end, i.e. it 'goes in a circle". Third, the facet scales themselves vary in terms of their closeness to the boundaries of the conical regions to which they belong. For example, 'altruism' and 'deliberation' lie at the boundary of Agreeableness and Conscientiousness, while 'warmth' is located 'inside' the Conscientiousness region, and 'excitement-seeking', usually considered to be an Extraversion marker, is located inside the Openness region. Hence, there is a smooth transition from one region to the next. Thus, while the Big Five claim is that the five sets of facet scales are orthogonal sets, this turns out to be nowhere near the truth for the NEO-PI. The orthogonality claim evidently reflects a conflation of the rectilinear coordinate system of an orthogonal common factor space with the 'structure' itself. The NEO-PI facet scales have a very special type of (partially ordered) correlation structure. It would not arise if any two sets of facet scales, e.g. Neuroticism and Agreeableness, were far more dissimilar than any other two sets. If this was the case, the five sets would be contained in distinct planar strips spanning the embedding space (i.e. they would form a general simplex). Finally, the facet scales vary in term of their distances from the origin of the radex. 'Aesthetics', 'positive emotions', and 'warmth' define the origin, while the Neuroticism facet scales are located at the periphery along with 'deliberation' and 'order'.

A more formal treatment of the features of the radex will later be given. However, certain of the features of the radex may harken back to the earlier discussion of the circumplex. This is understandable, for a radex is the pairing of two more elementary structures: The simplex and the circumplex. Psychologists may not be familiar with the theory that provides a sophisticated grounding for structures like the circumplex (relevant sources include Shepard, 1978; Shye, 1978; van den Wollenberg, 1978; and especially Guttman, 1957). At an elementary level, a simplex is a one-dimensional structure in which the embedding space is partitioned into an ordered set of regions,

Table 4. Descriptive statistics for Goldberg-40

Adjective	*M*	SD
Surgency		
Retiring–Sociable (S1)	6.45	1.45
Quiet–Talkative (S2)	6.00	1.87
Passive–Active (S3)	6.26	1.69
Submissive–Dominant (S4)	5.58	1.61
Timid–Bold (S5)	5.75	1.69
Proud–Humble (S6)	4.57	1.86
Unenergetic–Energetic (S7)	6.28	1.70
Conforming–Independent (S8)	6.26	1.88
Agreeableness		
Cold–Warm (A1)	7.24	1.16
Selfish–Selfless (A2)	6.00	1.49
Suspicious–Trusting (A3)	5.92	1.93
Stingy–Generous (A4)	6.63	1.44
Critical–Lenient (A5)	5.17	1.66
Disagreeable–Agreeable (A6)	6.31	1.39
Stubborn–Flexible (A7)	5.32	2.16
Unfair–Fair (A8)	7.33	1.05
Conscientiousness		
Negligent–Conscientious (CON1)	7.14	1.30
Careless–Careful (CON2)	6.90	1.73
Undependable–Reliable (CON3)	7.61	1.38
Lazy–Hardworking (CON4)	6.69	2.06
Disorganized–Organized (CON5)	6.40	2.11
Impractical–Practical (CON6)	6.59	1.36
Conservative–Liberal (CON7)	5.15	1.99
Traditional–Untradit. (CON8)	5.52	2.31
Neuroticism		
Unstable–Stable (N1)	3.73	1.86
At ease–Nervous (N2)	5.48	2.04
Relaxed–Highly strung (N3)	5.08	2.00
Unemotional–Emotional (N4)	6.61	1.71
Even-tempered–Tempermen. (N5)	5.10	2.08
Secure–Insecure (N6)	4.83	2.07
Not-envious–Envious (N7)	4.87	1.95
Objective–Subjective (N8)	5.21	1.72
Culture		
Ignorant–Knowledgeable (CUL1)	6.92	1.24
Stupid–Intelligent (CUL2)	7.27	1.28
Imperceptive–Perceptive (CUL3)	6.92	1.21
Uncultured–Cultured (CUL4)	6.59	1.69
Uncreative–Creative (CUL5)	5.92	1.95
Simple–Complex (CUL6)	6.25	2.16
Uncurious–Curious (CUL7)	7.47	1.30
Unanalytic–Analytic (CUL8)	6.76	1.46

the ordering corresponding to (or induced by) a single characteristic of the variables (Shye, 1978). A circumplex is of minimum dimensionality two, and represents a partial ordering of a set of variables with respect to a number of characteristics. Finally, the variables that comprise a radex are organized empirically both with respect to a circumplex and a simplex. The positioning of each variable in the simplex determines its distance from the origin, while its position in the circumplex determines its angular displacement (i.e. position around the circle).

STUDY 2

Method

The Goldberg-40 is a set of 40 adjective pairs, the members of each pair positioned at opposite ends of a nine-point Likert scale. It was administered to a sample of 215 Psychology undergraduates at Simon Fraser University during the spring of 1996. Participants completed the rating task as part of an introductory psychology course credit. Of the sample, 64% were women and 36% were men. Table 4 provides the means and variances of the Goldberg-40 scales.

The matrix of Pearson product–moment correlations was calculated for the 40 adjective pairs and NMDS (Kruskal's monotone regression, primary approach to ties) was applied.

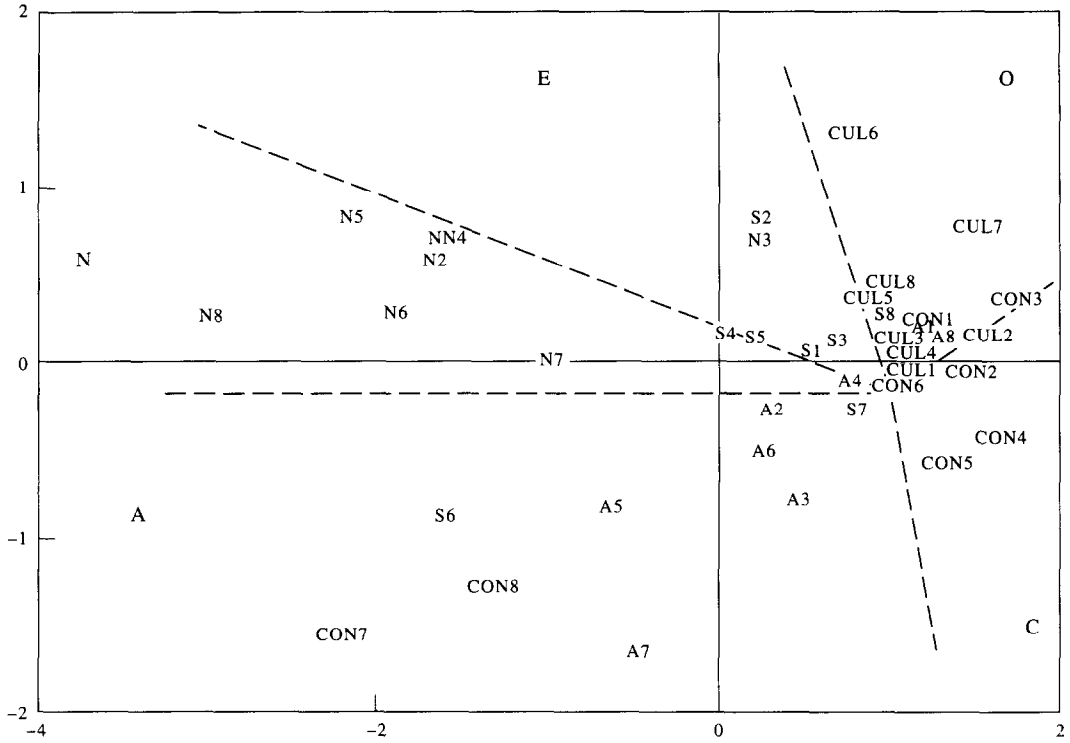

Fig. 4. Two-dimensional NMDS for Goldberg-40.

RESULTS

Figure 4 depicts the NMDS representation of the Goldberg-40. Once again, only 'two' dimensions were required to adequately summarize the relations among the variables (stress = 0.09). Furthermore, the structure depicted in Fig. 4 is, once again, a radex. The adjective scales are found, in general, within five conical regions that correspond to Goldberg's prior substantive classification. The violations to this arrangement were as follows: Relaxed–Highly strung (a Neuroticism scale) was found in the Surgency region; Proud–Humble (a Surgency scale) was found in the Agreeableness region; Conservative–Liberal and Traditional–Untraditional (both Conscientiousness scales) were found within the Agreeableness region; Cold–Warm and Unfair–Fair (both Agreeableness scales) were found within the Culture region. There were, in addition, four marginal violations. Second, the circular ordering of the five conical regions was the same as for the NEO-PI except that Extraversion (Surgency) and Openness (Culture) changed places. Finally, the Neuroticism scales, just as for the NEO-PI, were located far from the origin of the radex, which was defined by Stingy–Generous, Impractical–Practical, and Unenergetic–Energetic.

DISCUSSION

A rationale for the radex

It should be emphasized that the generation of correct structural representations does not require, in advance, a complete explanation of that which is represented. Astronomy, for example, is in the business of giving a correct depiction of space regardless of the sophistication of currently available explanations. What is clear is that accurate representation is a prerequisite for correct theorizing about that which is represented. Hence, all that is required here is that the radex *is* the correct structure of at least the NEO-PI and Goldberg-40. A full explanation of *why* this is the case could be deferred. As an aside it should be recalled that the Big Five movement itself gathered momentum as a result of nothing more than the repeated occurrence of a particular factor pattern. However, it so happens that there already exists a detailed and sophisticated theory for the 'explanation' of structures like the radex. This theory goes by the name of Guttman facet theory (Canter, 1985;

Elizur & Guttman, 1976; Guttman & Levy, 1991; Schlesinger & Guttman, 1969; Shye, 1978), and provides an interesting perspective on the substantive grounding of the radex of Figs 3 and 4. In facet theory, one constructs a facet definition for a domain of items, the facet definition describing the characteristics of each item as the intersection of one level from each of a number of facets. A facet is, roughly speaking, a factor on which item characteristics vary. The set of levels that describes the content of an item is its structuple. Hence, an item domain as a whole is described as the Cartesian product of a number of facets each with a number of levels, and this description is compactly represented as a facet definition. Facet analysis is, in addition, a tool used to formulate hypotheses about the 'empirical' structure of items drawn from a domain of items, and this makes it particularly useful in clarifying structural issues of the type addressed in the current work. Structural hypotheses are formulated by considering the number and types of facet present in the facet definition that describes the domain (Shye, 1993). Guttman and his associates have established the empirical structures to be expected from item domains characterized by many different types of facet definition. Famous examples include the simplex, multiplex, circumplex, radex, and cylindrex (see Shye, 1978), the latter three of which are distinctive in their circular geometry.

Guttman theory states that if a domain of items is described by a facet definition containing one facet with unordered levels (called a polarizing facet), and one facet with ordered levels (called a modulating facet), and one level of the modulating facet can be seen as a substantive origin for the variables, then a reasonably large set of variables drawn from this domain will typically have an empirical radex structure (Schlesinger & Guttman, 1969). Furthermore, the variables will be arranged regionally according to their assigned structuples. That is, variables with the same structuple will be located in the same region of the embedding space. The polarizing facet divides the space into conical regions emanating from a common origin, the number of regions being equal to the number of levels in the polarizing facet. The modulating facet further divides the space by the super-imposition of concentric circles about the origin, the number of circles being equal to the number of levels in the modulating facet. The current work already hinted at one such radex, the radex of colour perception (Shepard, 1978) in which hue plays the role of polarizing facet and saturation plays the role of modulating facet (Shepard, 1978). If, on the other hand, a domain of variables is described by a single unordered (polarizing) facet, the variables will typically have an empirical circumplex structure (Levy, 1985). That is, the polarizing facet will divide the space into a set of conical regions, but the variables will be equidistant from the origin of the structure. A circumplex can therefore be viewed as a radex in which all of the variables are at the same level of a modulating facet, resulting in a structure with a hollow interior. In the circumplex of colour perception (see Fig. 1), hue plays the role of polarizing facet, with saturation held constant. In contrast to the circumplex is the case in which a single 'ordered' (axial) facet describes a domain of variables. The structural hypothesis in this case is a general simplex, with variables described by the first and last levels of the facet a maximum distance apart. The hypothesized relationships between facet definition and the radex, circumplex, and simplex are depicted in Fig. 5.

The complexity of a structure will, in general, increase with the number of ordered and unordered facets required to describe an item domain.

The NEO-PI facet scales and Goldberg-40 have a radex structure. Can they be described by a facet definition with one modulating and one polarizing facet? The answer is in the affirmative. Figure 6 provides a facet definition for the 30 facet scales of the NEO-PI.

There are two facets that jointly characterize the NEO-PI. 'Kind' is the primary classifier since it specifies the kind of behaviour measured by each facet scale. There are five levels to this facet. 'Integrative Centrality', on the other hand, is a modifying facet, since it merely classifies the type of behaviour in question. The idea of 'Integrative Centrality' (see Shye, 1993) is just that variables differ in the degree to which they 'go together' empirically with other variables (of all 'Kinds') in the manifestation of personality. Certain variables are drawn to the centre of the radex because they have higher average correlations with the other variables in the variable domain. The 'Kind' facet plays the role of polarizing facet, there being no order implied by the relationships among its elements. The 'Integrative Centrality' facet, on the other hand, is a modulating facet since the high to low modifiers are clearly ordered, with 'high' playing the role of origin for the variables. By choosing an element from each of the two facets, each facet scale is described by a two-element structuple. Finally, each person is mapped into an ordered metric (i.e. high to low score or strong

Facet Definition	Hypothesized Structure
Contains 1 ordered (axial) facet with p levels	Simplex: 1 2 . p
Contains 1 unordered (polarizing) facet with p levels	Circumplex: 1, 2, p, .
Contains 1 unordered (polarizing) facet with p levels, and 1 ordered (modulating) facet with q levels	Radex: 1q, 2q, 1., 2., 11, 21, p1, .1, p., .., pq, .q

Fig. 5. Empirical structures and corresponding facet definition.

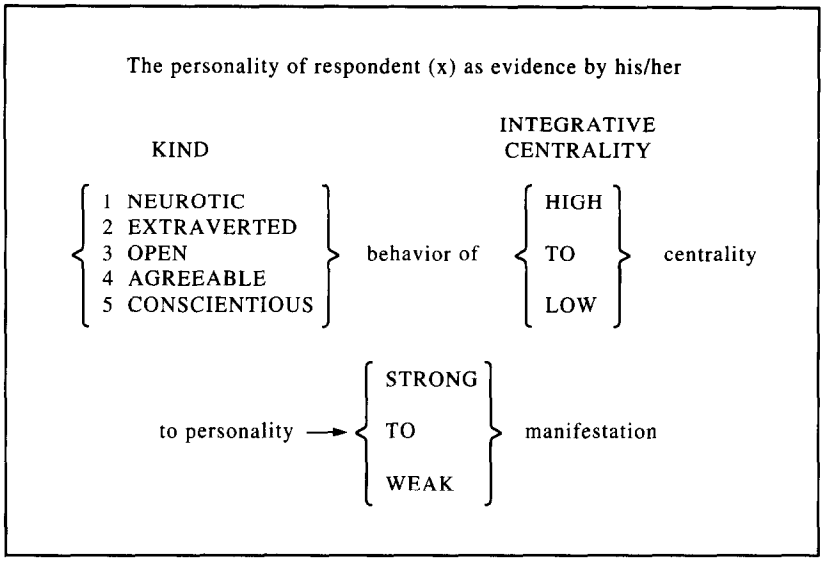

Fig. 6

to weak manifestation) on each facet scale when they take the NEO-PI. Hence, this is the range of the facet definition. This definition, with a slight specialization to the range to make it appropriate for bi-polar adjective scales, also describes the Goldberg-40. The structuples associated with each NEO-PI facet scale are provided in Table 5.

The smaller the number, the higher the integrative centrality of the facet scale. Accordingly, 'aesthetics', 'positive emotions', and 'warmth' have high integrative centrality while the Neuroticism facet scales have low integrative centrality, as do 'deliberation' and 'order'. The scientific importance of this structural feature is not trivial. For our focus here is on the correlation structure of the

Table 5. NEO-PI facet scales and associated structuples

Facet scale	Structuple
Anxiety	K_1I_5
Angry hostility	K_1I_6
Depression	K_1I_6
Self-conscientiousness	K_1I_5
Impulsiveness	K_1I_4
Vulnerability	K_1I_6
Warmth	K_2I_1
Gregariousness	K_2I_2
Assertiveness	K_2I_3
Activity	K_2I_2
Excitement-seeking	K_2I_3
Positive emotions	K_2I_1
Fantasy	K_3I_3
Aesthetics	K_3I_1
Feelings	K_3I_1
Actions	K_3I_2
Ideas	K_3I_3
Values	K_3I_3
Trust	K_4I_2
Straightforwardness	K_4I_3
Altruism	K_4I_2
Compliance	K_4I_3
Modesty	K_4I_3
Tender-mindedness	K_4I_1
Competence	K_5I_4
Order	K_5I_4
Dutifulness	K_5I_4
Acheivement striving	K_5I_3
Self-discipline	K_5I_4
Deliberation	K_5I_5

Note: K_i is the i^{th} level of the 'Kind' facet; I_j is the j^{th} level of the 'Integrative Centrality' facet.

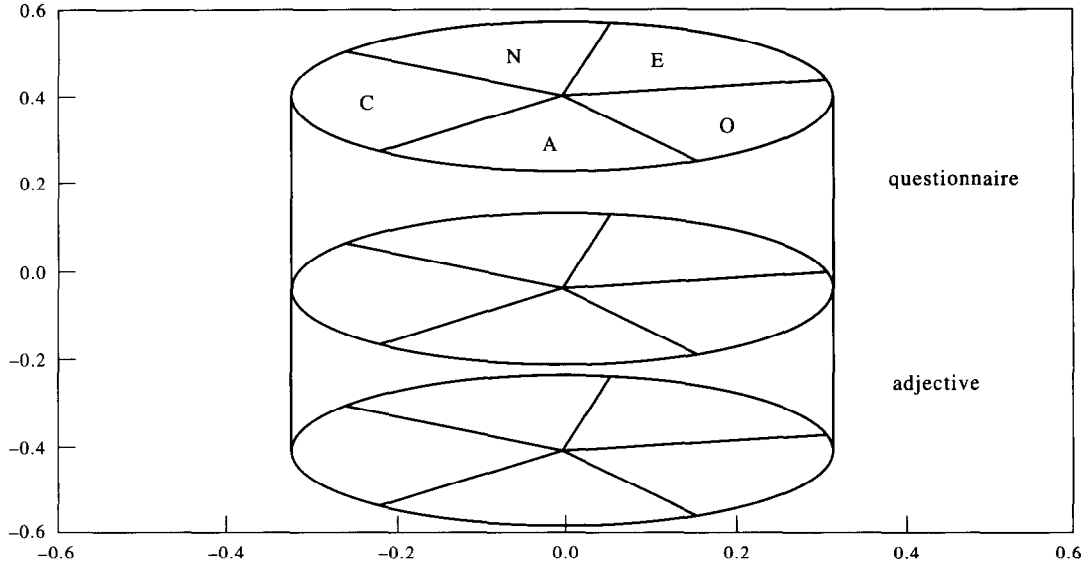

Fig. 7. Cylindrex structural hypothesis for Big Five domain?

variables, and integrative centrality describes the fact that the variables (despite differing in 'kind') are organized around a structural core. The variables differ in the degree to which they conjoin with other variables, but this is *not* a function of 'Kind'. It need not have been this way: The 'Kind' distinction alone may have induced a simplex ordering with no common centre for the variables. On an historical note, the radex is in keeping with a number of previous conceptions of personality variables. For example, the "interpersonal system of Personality diagnosis" (Kiesler, 1983; Leary, 1957; Wiggins, 1973, p. 480; Wiggins, 1982) does not, as is sometimes thought, provide grounds for the hypothesis of a circumplex, but instead a radex. This is because it describes a domain of trait descriptors structured both in terms of 'Kind' and 'Intensity' (mild to severe). 'Kind', in this system, plays the same role as it does in the facet definition of Fig. 6, while 'Intensity' plays an analogous role to that of integrative centrality. Hence, the domain of variables implied by the interpersonal system is described by a facet definition containing one polarizing and one modulating facet.

Clearly the implication of this discussion is that the structure of Big Five variables in general (i.e. trait descriptors) may well be something like a radex. The rationale is the same as that provided for the NEO-PI and Goldberg-40. That is, that Big Five variables in general can be described by a facet definition that includes at least the polarizing facet of 'Kind', and the modulating facet of 'Integrative Centrality'. Now, any serious attempt to formulate a structural hypothesis would require that attention be given to the different measurement formats (e.g. questionnaire vs adjective scales) that may be employed. The accommodation of this additional facet (i.e. measurement format) would result in the hypothesis of a three-dimensional 'cylindrex' for the domain of Big Five variables (see Levy & Guttman, 1981). A cylindrex is a set of stacked radexes, in this case one radex for each measurement format. The cylindrex of Fig. 7 depicts the special case in which measurement format is restricted to two levels, namely, the adjective scale (e.g. the Goldberg-40) and the questionnaire (e.g. the NEO-PI). The structural hypothesis (not tested in the present work) is that Big Five variables are organized in a three-dimensional space according to their structuples from three facets: 'Kind', 'Integrative Centrality', and 'Measurement Format'.

Integration of distinct domains

Recently, a great deal of effort has been devoted to attempts to reconcile different personality formulations, especially the so-called interpersonal circle and Big Five formulations (e.g. Hofstee, de Raad & Goldberg, 1992; McCrae & Costa, 1989a). The coherent treatment of the issue of integration requires that clear aims be specified: What are the senses in which integration is of interest? On the one hand, integration may involve the derivation of bridging rules to link the content of two or more distinct item domains. On the other hand, it may involve the investigation

of the joint 'empirical' structure of variables drawn from two distinct variable domains. Obviously, these are radically different senses of integration. By way of example, the findings of McCrae and Costa (1989a) are an attempt to derive the joint empirical structure of interpersonal variables (represented by Wiggin's, 1979, IAS scales) and Big Five variables (represented by the NEO-PI, McCrae & Costa, 1985). Unfortunately, for reasons previously discussed, their method (factor analysis plus DISS) does not, in fact, constitute an examination of joint structure. Hofstee *et al.* (1992), on the other hand, is not, despite appearances, an investigation of joint empirical structure. In fact, the work of Hofstee *et al.* should not even be taken as a test of the circumplexity of variables drawn from the Big Five content domain, for, in this study, the structure of Big Five variables was not investigated. Instead, a set of construction rules were used to 'assemble' circumplex depictions of the variables.

What is central to the present work is the derivation of bridging rules to link distinct item domains, and that, through facet theory, can be turned into hypotheses of joint empirical structure. The focus here is once again on the interpersonal and Big Five variable domains. The discussion to this point implies that circular orderings should play a prominent role. To recall, the empirical structure of a set of variables may be expected to contain a circular ordering if the domain from which the variables were drawn is described by a facet definition containing at least one unordered (polarizing) facet. The radex and circumplex are two of the simplest structures containing a circular ordering of variables. It has already been shown how the NEO-PI and Goldberg-40 are described by a facet definition that includes a polarizing facet, and that both have radex structures. The circumplex of colour perception (with saturation held constant), on the other hand, arises from a content domain that is described by a single polarizing facet (i.e. hue). How are circumplex and radex variable domains linked, if at all? In general, if two distinct variable domains are described by facet definitions that contain the same modulating and polarizing facets, but each polarizing facet contains a 'different' set of levels, it may be expected that the joint empirical structure of variables drawn from the two domains will be a radex. The rationale is as follows:

(1) The mere addition or deletion of elements from a polarizing facet will not, in general, change the resulting structure.
(2) As has often been noted, the Interpersonal and Big Five treatments differ in terms of content coverage, with the former centring exclusively on Extraversion and Agreeableness (McCrae & Costa, 1989a), and the latter including, in addition, Conscientiousness, Neuroticism, and Openness.
(3) This difference is merely a difference in the number of levels of the 'Kind' facet required to describe each domain; and furthermore, the two domains share the same modulating facet, that being Integrative Centrality.
(4) Hence, the facet definition of Fig. 5 suffices to describe the content domains that underlie 'both' models.

As long as the format of measurement is held constant, the hypothesized joint empirical structure is therefore a radex, in which, e.g. Wiggins IAS variables lie at a fixed distance from the origin (i.e. comprise a single circumplex in the radex), and, e.g. the NEO-PI facet scales vary in terms of their distances from the origin. One gets a hint of this even from studying McCrae and Costa's (1989a) factor analytic results. These results show a number of the NEO-PI facet scales as lying internal to the circumplex defined by the IAS variables. If, in addition, adjective scales were included to represent the Big Five domain then, as before, the hypothesized structure would be a three-dimensional cylindrex.

CONCLUSION

Contrary to what is probably the initial opinion of the reader, circumplex, radex, and related structures *do* arise frequently in personality research. This may well be because many personality variable domains implicitly involve the 'Kind/Integrative Centrality' characterization. The Basic Personality Inventory (Jackson, 1989), for example, has a radex structure (Maraun & Chrisjohn, 1995). As Shepard (1978) states:

> " ... when in 1954 Guttman first published his new notions of the circumplex and its generalization, the radex, I was highly sceptical of the claim that these particular sorts of circular structures should underlie even correlations among mental tests—let alone other, quite different, types of data ... the circumplex has, despite my initial scepticism, subsequently emerged in various guises out of my own data and analyses in the field of perception ... "

Furthermore, at a time when integration is so central to personality psychology it might be well worth considering the theory that spawned the circumplex: facet theory. As distinct from *ad hoc* approaches, facet theory can provide a rigorous characterization of variable domains, and a sophisticated basis for the generation of structural hypotheses. It is easily seen, for example, that according to the facet theory principles described here, the 'problematic' cognitive personality disorders, which apparently have a simplex structure, and the remaining personality disorders, which have a circumplex structure (see Romney & Bynner, 1992), should have a joint radex structure. The different 'Kinds' of disorder, including the cognitive disorders are incorporated as levels of a common polarizing facet, while an 'Extremity' facet plays a modulating role. Interestingly, the 'Type/Extremity' characterization of personality disorders is really nothing but Leary's 1957 model.

It is common to refer to the Big Five and interpersonal circumplex as 'models' of personality. A model is a human construction. It may stimulate thought, suggest useful scientific leads, provide a basis for prediction, or represent and systematize acquired knowledge (see Bijleveld, 1989). It may also have empirical implications, implications that are formalized in its mathematical structure (e.g. as in co-variance structure analysis). To the extent that the Big Five and interpersonal circumplex are models, this paper has little to say about them. However, the Big Five claim arose from empirical analyses of the correlation structure of sets of variables, and it is to this issue, the issue of empirical structure, which this paper is primarily addressed. The conclusions are that:

(1) Whatever be the structure of variables drawn from the Big Five domain, the programme of research featuring factor analysis and the DISS procedure does not involve an analysis of structure. Hence, the structure of Big Five variables is an open issue.
(2) The NEO-PI and Goldberg-40, whose structures are supposedly in keeping with the Big Five, actually have radex structures.
(3) Facet theory provides a powerful basis for the generation of structural hypotheses. The facet theory hypotheses are that:
    (i) Big Five variables (with measurement format held constant) will have an empirical radex structure;
    (ii) without measurement format held constant, they will have an empirical cylindrex structure;
    (iii) the joint empirical structure of Big Five and interpersonal (circumplex) variables will be a cylindrex;
(4) Structures with circular orderings arise naturally in personality psychology because polarizing facets are frequently required to describe domains of variables.

Regardless of whether these structural hypotheses turn out to be correct, what is certain is that without a careful distinction being made between model, structure, representation, and mode of representation, and without the employment of appropriate methods for structural analysis, personality researchers are destined to confuse mere appearance with reality.

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