*Multivariate Experimental Clinical Research*, Volume 7, No. 3, 1985, 113-122.

# CANONICAL/REDUNDANCY ANALYSES OF THE SIXTEEN PERSONALITY FACTOR QUESTIONNAIRE, THE MOTIVATION ANALYSIS TEST, AND THE EIGHT STATE QUESTIONNAIRE

Gregory J. Boyle*
University of Melbourne, Australia

Gordon V. Stanley
University of Melbourne, Australia

K. Brian Start
University of Melbourne, Australia

*The authors are indebted to Dr. Charles Poole, University of Melbourne, and to Dr. Maurice Tatsuoka, University of Illinois at Urbana-Champaign, for their helpful advice on some aspects of this research.

## ABSTRACT

The present study investigated the measurement overlap between the Sixteen Personality Factor Questionnaire (16PF), the Motivation Analysis Test (MAT), and the Eight State Questionnaire (8SQ). these multivariate instruments pertain to the psychological domains of personality, motivation and mood respectively. Canonical/redundancy analysis (Stewart & Love, 1968) was employed on a sample of 258 Australian college students for the 8SQ/MAT measures, and on a subsample of 135 students for the 16PF/MAT and 16PF/8SQ measures. Results demonstrated a marginal overlap in measurement variance for the 16PF and 8SQ, while only very slight redundancy was observed for the 16PF/MAT and 8SQ/MAT intersections. It was concluded that all three instruments are efficient measures of essentially separate psychological modalities.

Cattell (1982a; 1983) and Kline (1979; 1980) drew a sharp distinction between enduring personality traits, less stable motivational dynamic traits, and constantly fluctuating, transient emotional states. According to both Cattell and Kline, these discrete psychological domains are not mutually interdependent. Since measurement of each domain is purported to tap discrete psychological variance, efficient representation in each case demands the use of essentially unrelated measurement variables (Wakefield & Carlson, 1975).

Conceivably, measures of the three domains, despite the assertions of Cattell and Kline, are all interdependent, so that measurement overlap between pairs of such measures might reasonably be expected. One technique for determining level of overlap between measures of the three domains is canonical analysis together with Stewart and Love's (1968) redundancy index (Krug, 1978). Other methods such as multiple regression with individual variables, discriminant function analysis, and even factor analysis might be used, or possibly even bipartial canonical analysis (Timm & Carlson, 1976). The canonical/redundancy method, however, allows a precise quantitative estimate of the extent of overlap between pairs of measures and is therefore quite appropriate. Traditional use of canonical analysis in isolation would suggest the number of ways in which pairs of measures are related, as well as the strengths and nature of such relationships (Veldman, 1967), but the resultant canonical pairs most likely would only partially reflect the actual nature of the data (Warwick, 1975). Since the purpose of the present study was to estimate the measurement overlap of the 16PF (Cattell, Eber, & Tatsuoka, 1970), MAT (Cattell, Horn, Sweney, & Radcliffe, 1964), and 8SQ (Curran & Cattell, 1976), there was little point in rotating the canonical vectors to optimal simple structure, as enunciated for example, by Cliff and Krus (1976).

Tatsuoka (Note 1) contended that canonical analysis alone is of little conceptual value, being effectively "double-barrelled principal components analysis." Nevertheless its use with Stewart and Love's (1968) redundancy index has received considerable validational support (e.g., Gleeson, 1976; van den Wollenberg, 1977; DeSarbo, 1981; Johansson, 1981; Muller, 1981). According to Krug (1978, p. 201), "The canonical correlation model is particularly appropriate for examining the interrelationships between two variable domains. . . . When used along with the 'redundancy index' developed by Stewart and Love (1968), it becomes even more powerful and still avoids theoretical controversies regarding methods of extraction and rotational techniques if the joint matrix were to be fully factor analysed. The redundancy indices provide overall measures of how much variance in one set of variables is accounted for by the other set." While some questions have been raised about the use of Stewart and Love's redundancy index (Amick & Walberg, 1975), these cautions were not sufficiently injurious as to invalidate the index as a measure of redundancy. The present study therefore used this method in order to quantify the overlap in measurement of the 16PF, MAT and 8SQ.

## METHOD

### SUBJECTS

All subjects were student teachers attending the Institute of Catholic Education, Melbourne. Data on both the MAT and 8SQ was analysed for 258 students, whose mean age was about 22 years, ranging from 18 to 47 years, and whom virtually all were females. However, the 16PF/MAT, and 8SQ/16PF analyses were based on a subsample of 135 of these students (only 135 students had taken the 16PF). Examination of mean scores for the 16PF, MAT and 8SQ subscales revealed some sex differences. However in most instances these slight differences in mean scores were nonsignificant, which suggested that the canonical/ redundancy analyses could be performed validly on the combined-sex data.

Hence it was not deemed necessary to test the covariance matrices for between-sex homogeneity. Almost all students came from a predominantly middle-class socioeconomic background.

## INSTRUMENTS

As indicated in the Manual for the 16PF, the instrument was designed to measure independent factorial dimensions of personality structure (I.P.A.T., 1972). Despite some reservations (Bloxom, 1978), the 16PF appears to be as reliable and valid as most other personality inventories (Bolton, 1978). Moreover, Bolton (1979) has demonstrated that the 16PF is reasonably stable over periods of six years or more with test-retest (stability) coefficients for several of the subscales being in excess of .50 ($p \pm .001$). The MAT, comprised of objective items, is purported to measure ten separate motive structures (Cattell & Child, 1975). According to them, the MAT dynamic states/traits are out in new hyperspace as only 26% of the intercorrelations between the 16PF and MAT factors were significant (in the present study, 27% of the 16PF/MAT intercorrelations were significant) at the 5% level. The 8SQ is purported to measure eight important emotional states. Despite assertions by Kleinmuntz (1978) that the 8SQ subscales lack reliability, Curran and Cattell (1976, pp. 14-15) reported short-term test-retest (dependability) coefficients ranging from .91 to .96 (mean .94). Stability coefficients for a one-week retest interval averaged .36 (which for state measures is expected — Zuckerman, 1983). Boyle (1984) reported three-week retest correlations for the 8SQ subscales ranging from .44 to .72, and $KR_{21}$ estimates ranging from .49 to .87 (mean .74). While only 9% of the intercorrelations between the 8SQ and MAT integrated (I) dynamics were significant at the 5% level, 39% of the intercorrelations between the 8SQ and MAT unintegrated (U) dynamics were significant in Boyle's study.

## PROCEDURE

Each multivariate instrument was prefaced by standard instructions and responses were marked on separate answer sheets. The mean time for completing the 8SQ was about 20-25 minutes. The 16PF took about 50 minutes, while the MAT required almost an hour to complete. Each subscale in all three measures was scored separately. A number of separate classes of students were given the three measures. Each class comprised about 15-20 students. Total testing time ranged from about two hours to two and one half hours, depending on the work habits of the particular student.

# RESULTS AND DISCUSSION

Canonical analyses were performed using Program CANONA (Veldman, 1967). Computation of the redundancy indices was by the Stewart and Love (1968) method. While the obtained canonical weights indicated the structure of the components (Cooley & Lohnes, 1971; Darlington, Weinberg, & Walberg, 1975; Thorndike & Weiss, 1973; 1983), it was the squared canonical loadings which were of interest in the present context (Thorndike, 1977). For the 8SQ and MAT data, three vectors were significant at the 5% level. Canonical Variate 1 (Root = .26) contrasted the factors U-Career, U-Home, U-Self-Sentiment, U-Sweetheart, I-Narcism, Extraversion and Arousal with the factors U-Pugnacity, U-Assertiveness, Anxiety, Depression, Regression and Guilt. Significant canonical loadings were taken as being .25 or greater for the MAT subscales and .51 or greater for the 8SQ subscales. Variate 2 (Root = .19) contrasted the factors U-Mating, U-Sweetheart and Extraversion with I-Fear, I-Narcism, I-Superego and I-Self-Sentiment. Variate 3 (Root = .15) contrasted U-Career, I-Career, I-Assertiveness and Extraversion with U-Mating, I-Superego, I-Sweetheart, Stress and Fatigue. While qualitative interpretation of these loadings was not the primary concern, it is nevertheless, interesting to note the similarity of these findings with the Extraversion-Introversion concept postulated by Eysenck (Lynn, 1981). As all three variates were significant, it is evident that there was some significant overlap in measurement variance of the 8SQ and MAT.

Weiss (1976) contended that it is only by considering the variance from all possible canonical correlations that the redundancy can be determined. However, Weiss was not entirely correct about redundancy. Total redundancy requires extraction of the complete set of canonical relationships. Given the fallibility of most psychological data though, it seems unjustified to go beyond the significant roots to describe the degree of overlap between sets. The test of significance is one of equality of the remaining roots. Conceptually this is similar to Bartlett's test for principal components, and hence it is unclear what meaning can be drawn from the total redundancy values or from the later roots. When two batteries differ in size, unequal redundancy and variance extracted would be expected. Given this rationale, 85% of 8SQ variance and 71% of MAT variance associated with only the three significant canonical vectors was extracted. In this context, 15% of the 8SQ variance was accounted for by the MAT, whereas only 4% of MAT variance was measured in the 8SQ (see Table 1). Evidently the MAT and 8SQ are essentially independent instruments with little (albeit statistically significant) measurement overlap between them. In practical terms, this slight overlap is inconsequential.

## Table 1
## CALCULATION OF REDUNDANCY ESTIMATES FOR 8SQ AND MAT

| Root | Canonical R (Rc) | R Squared (λ) | Variance Extracted (VC) | Redundancy (λ VC) |
|---|---|---|---|---|
| 1 | .5069 | .2569 | .421 | .108 |
| 8SQ 2 | .4372 | .1912 | .051 | .010 |
| 3 | .3822 | .1461 | .183 | .027 |
| 1 | .5069 | .2569 | .062 | .016 |
| MAT 2 | .4372 | .1912 | .051 | .011 |
| 3 | .3822 | .1461 | .065 | .010 |

Notes: Redundancy calculated for significant roots only.
Redundancy of 8SQ given MAT = .145
Redundancy of MAT given 8SQ = .037

The canonical analysis on the 8SQ and 16PF data revealed that once again three vectors were significant. Variate 1 (Root = .52) contrasted the 16PF Factors A, C, E, F, H and M (see Cattell et al., 1970, for a complete description of the 16PF subscales) and the 8SQ subscales of Extraversion and Arousal with Factors O, $Q_2$, $Q_4$, Anxiety, Depression, Regression and Fatigue. Variate 2 (Root = .27) contrasted Factors E, F, O, $Q_4$ and the 8SQ subscales of Guilt with Factors C and $Q_3$. Variate 3 (Root = .26) contrasted Factors G, $Q_2$, $Q_3$ and Arousal with Factors O and $Q_4$, as well as Fatigue. Significant canonical loadings for the 16PF subscales were taken as .25 or greater. The corresponding redundancy calculations are presented in Table 2. For the three significant canonical vectors, the 8SQ predicted 14% of the 16PF variance, while the 16PF accounted for 24% of the 8SQ measurement variance. Clearly there was a significant, but small degree of measurement overlap between these two instruments. Part of this overlap can be accounted for in state-trait terms. Whereas the 16PF measures personality traits, the 8SQ measures less stable emotional states, which nevertheless, bear a direct relationship to the more enduring traits (for example, Anxiety is an 8SQ factor, but is it also a second-order 16PF factor). Consequently the small degree of overlap in measurement variance between the 8SQ and 16PF must be regarded as marginal.

## Table 2
## CALCULATION OF REDUNDANCY ESTIMATES FOR 8SQ AND 16PF

| Root | Canonical R (Rc) | R Squared (λ) | Variance Extracted (VC) | Redundancy (λ VC) |
|---|---|---|---|---|
| 1 | .7177 | .5151 | .339 | .175 |
| 8SQ 2 | .5159 | .2662 | .093 | .025 |
| 3 | .5071 | .2572 | .152 | .039 |
| 1 | .7177 | .5151 | .177 | .091 |
| 16PF 2 | .5159 | .2662 | .093 | .025 |
| 3 | .5071 | .2572 | .091 | .023 |

Notes: Redundancy calculated for significant roots only.
Redundancy of 8SQ given 16PF = .239
Redundancy of 16PF given 8SQ = .139

As for the data on the 16PF and MAT, four significant canonical vectors emerged from the analysis. Variate 1 (Root = .35) contrasted U-Fear, U-Mating, U-Sweetheart and Factors E, F, H and L with U-Home, I-Narcism, I-Assertiveness and Factors A, N and $Q_2$. Variate 2 (Root = .45) contrasted U-Superego, U-Pugnacity, I-Home, I-Narcism and Factors G and $Q_3$ with I-Assertiveness and Factors $Q_1$ and $Q_4$. Variate 3 (Root = .37) contrasted U-Self-Sentiment, I-Fear, I-Self-Sentiment and Factors G, I and M with I-Pugnacity, I-Assertiveness and Factor $Q_2$. Variate 4 (Root = .31) contrasted U-Narcism, I-Self-Sentiment and also Factors B and $Q_1$ with U-Home, U-Assertiveness, I-Home, I-Superego and Factors A, O and $Q_4$. Redundancy estimates revealed that the 16PF predicted 10% of the MAT variance, while the MAT accounted for 13% of the 16PF variance for the four vectors. The redundancy calculations are presented in Table 3.

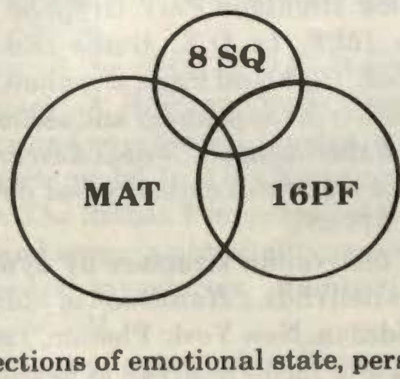
## Table 3
## CALCULATION OF REDUNDANCY ESTIMATES FOR MAT AND 16PF

| | Root | Canonical R (Rc) | R Squared (λ) | Variance Extracted (VC) | Redundancy (λ VC) |
|---|---|---|---|---|---|
| MAT | 1 | .6951 | .4831 | .066 | .032 |
| | 2 | .6744 | .4548 | .062 | .028 |
| | 3 | .6060 | .3672 | .070 | .026 |
| | 4 | .5567 | .3099 | .057 | .018 |
| 16PF | 1 | .6951 | .4831 | .099 | .048 |
| | 2 | .6744 | .4548 | .073 | .033 |
| | 3 | .6060 | .3672 | .070 | .026 |
| | 4 | .5567 | .3099 | .068 | .021 |

Notes: Redundancy calculated for significant roots only.
Redundancy of MAT given 16PF = .104
Redundancy of 16PF given MAT = .128

### CONCLUSIONS

While the present findings revealed a small amount of redundancy between the 16PF and 8SQ (measures of similar constructs, albeit in trait and state domains respecively), there was little apparent overlap in measurement variance between the 16PF and MAT, or between the 8SQ and MAT. The intersections investigated in the canonical/redundancy analyses can be visualized as shown in Figure 1.




Insert Figure 1. Intersections of emotional state, personality trait, motivational dynamic domains.

On the present findings, the claim by both Cattell (1983) and Kline (1980) concerning the relative independence of the personality trait, motivational state/dynamic trait, and emotional state domains seems justified. The extreme position of Wakefield and Carlson (1975) that similar measures should exhibit no overlap, and that such measures should be restructured to extirpate any slight redundancy seems untenable. The marginal overlap between the 16PF and 8SQ should not be taken to suggest that part of one of the measures should be eliminated. Both measures will not always be administered together. The slight overlap in measurement beteen the 16PF/MAT/8SQ measures suggests that all three instruments may be administered with little concern on the part of the investigator over measurement redundancy.

As for the three-way overlap (see Figure 1), no single redundancy index is likely to be defined meaningfully. According to Tatsuoka (Note 1), a number of three-set redundancy indices might be computed, and which type of measure is employed would depend on what one wishes to say on the basis of the coefficient.[1] However, application of this procedure requires strict adherence to certain assumptions (cf. Isaac & Milligan, 1983), which it is not necessary to postulate for two sets' analyses such as used here.

---

[1]Tatsuoka pointed out that, "the percentage, on the average, of the variability of each variable in Set A "accounted for" by the variables in Sets B and C, might be computed as the average squared multiple R, $\overline{R^2_{a.b.c}}$, of the variables in Set A predicted, in turn, from those in the other two sets. Or, to keep the identities of Sets B and C separate, it might be better to compute $R^2_{a.b}$ and $R^2_{a.c}$ separately, and take their average: $(\overline{R^2_{a.b}} + \overline{R^2_{a.c}})/2$. The other type of three-set redundancy might be computed as $(\overline{R^2_{a.c}} + \overline{R^2_{b.c}})/2$, etc."

## REFERENCES

Amick, D.J., & Walberg, H.J. (Eds.). *Introductory multivariate analysis.* Berkeley: McCutchan, 1975.

Bloxom, B.M. Review of the 16PF. In O.K. Buros (Ed.), *The eighth mental measurements yearbook.* Highland Park: Gryphon, 1978.

Bolton, B. Review of the 16PF. In O.K. Buros (Ed.), *The eighth mental measurements yearbook.* Highland Park: Gryphon, 1978.

Bolton, B. Longitudinal stability of the primary and secondary dimensions of the 16PF-E. *Multivariate Experimental Clinical Research,* 1979, *4,* 67-71.

Boyle, G.J. Critical review of state-trait curiosity test development. *Motivation and Emotion,* 1983, *7,* 377-397.

Boyle, G.J. Elucidation of motivation structure by dynamic calculus. In J.R. Nesselroade & R.B. Cattell (Eds.), *Handbook of multivariate experimental psychology.* Second Edition, New York: Plenum, 1985 (in press).

Cattell, R.B. *The scientific use of factor analysis in behavioral and life sciences.* New York: Plenum, 1978.

Cattell, R.B. The development of Cattellian structured systems theory of personality: The VIDAS model. *Zeitschrift für Differentielle und Diagnostische Psychologie,* 1982, *3,* 7-25. (a)

Cattell, R.B. The psychometry of objective motivation measurement: A response to the critique of Cooper and Kline. *British Journal of Educational Psychology,* 1982, *52,* 234-241. (b)

Cattell, R.B. *Structured personality-learning theory: A wholistic multivariate research approach.* New York: Praeger, 1983.

Cattell, R.B., & Child, D. *Motivation and dynamic structure.* New York: Wiley-Halsted, 1975.

Cattell, R.B., Eber, H.W., & Tatsuoka, M. *Handbook for the Sixteen Personality Factor Questionnaire (16PF).* Champaign, Illinois: Institute for Personality and Ability Testing, 1970.

Cattell, R.B., Horn, J.L., Sweney, A.B., & Radcliffe, J. *Handbook for the Motivation Analysis Test.* Champaign, Illinois: Institute for Personality and Ability Testing, 1964.

Cliff, N., & Krus, D.J. Interpretation of canonical analysis: Rotated vs. unrotated solutions. *Psychometrika,* 1976, *41,* 35-42.

Cooley, W.W., & Lohnes, P.R. *Multivariate data analysis.* New York: Wiley, 1971.

Curran, J.P., & Cattell, R.B. *Manual for the Eight state Questionnaire.* Champaign, Illinois: Institute for Personality and Ability Testing, 1976.

Darlington, R.B., Weinberg, S.L., & Walberg, H.J. Canonical variate analysis and related techniques. In D.J. Amick & H.J. Walberg (Eds.), *Introductory multivariate analysis.* Berkeley: McCutchan, 1975.

DeSarbo, W.S. Canonical/redundancy factoring analysis. *Psychometrika,* 1981, *46,* 307-329.

Gleeson, T.C. On redundancy in canonical analysis *Psychological Bulletin,* 1976, *83,* 1004-1006.

Horst, P. Generalized canonical correlations and their applications to experimental data. *Journal of Clinical Psychology,* 1961, Monograph Supplement No. 14.

*Institute for Personaltiy and Ability Testing Manual for the 16PF.* Champaign, Illiois: Institute for Personality and Ability Testing, 1972.

Isaac, P.D., & Milligan, G.W. A comment on the use of canonical correlation in the analysis of contingency tables. *Psychological Bulletin,* 1983, *93,* 378-381.

Johansson, J.K. An extension of Wollenberg's redundancy analysis. *Psychometrika,* 1981, *46,* 93-103.

Kleinmuntz, B. Review of the 8SQ. In O.K. Buros (Ed.), *The eighth mental measurements yearbook.* Highland Park: Gryphon, 1978.

Kline, P. *Psychometrics and psychology.* London: Academic, 1979.

Kline, P. The psychometric model. In A.J. Chapman & D.M. Jones (Eds.), *Models of man.* Leicester: The British Psychological Society, 1980.

Krug, S.E. Reliability and scope in personality assessment: A comparison of the Cattell and Eysenck inventories. *Multivariate Experimental Clinical research,* 1978, *3,* 195-204.

Lynn, R. (Ed.), *Dimensions of personality: Papers in honour of H.J. Eysenck.* Oxford: Pergamon, 1981.

Morrison, D.F. *Multivarite statistical methods.* New York: McGraw-Hill, 1967.

Muller, K.E. Relationships between redundancy analysis, canonical correlation, and multivariate regression. *Psychometrika,* 1981, *46,* 139-142.

Stewart, D., & Love, W. A general canonical correlation index. *Psychological Bulletin*, 1968, *70*, 160-163.

Thorndike, R.M. Canonical analysis and predictor selection. *Journal of Multivariate Behavioral Research*, 1977, *12*, 75-87.

Thorndike, R.M., & Weiss, D.J. A study of the stability of canonical correlations and canonical components. *Educational and Psychological Measurement*, 1973, *33*, 183-196.

Timm, N.H., & Carlson, J.E. Part and bipartial canonical correlations analysis. *Psychometrika*, 1976, *41*, 159-176.

van den Wollenberg, A.L. Redundancy analysis: An alternative for canonical correlation analysis. *Psychometrika*, 1977, *42*, 207-219.

Veldman, D.J. *Fortran programming for the behavioral sciences.* New York: Holt, Rinehart & Winston, 1967.

Wakefield, J.A., & Carlson, R.E. Canonical analysis of the WISC and the ITPA. *Psychology in the Schools*, 1975, *12*, 18-20.

Warwick, P.V. Canonical correlation analysis: Sub-program Cancorr. In N.H. Nie, C.H. Hadlai Hull, J.G. Jenkins, K. Steinbrenner, & D.H. Bent, *Statistical package for the social sciences.* New York: McGraw-Hill, 1975.

Weiss, D.J. Multivariate procedures. In M.D. Dunnette (Ed.), *Handbook of industrial and organizational psychology.* Chicago: Rand McNally, 1976.

Zuckerman, M. The distinction between trait and state scales is not arbitrary: Comment on Allen and Potkay's "On the arbitrary distinction between traits and states." *Journal of Personality and Social Psychology*, 1983, *44*, 1083-1086.

## REFERENCE NOTE

[1]M.M. Tatsuoka, *Personal communication*, June 14, 1983.