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HOW MANY DIMENSIONS ARE NEEDED TO DESCRIBE TEMPERAMENT IN ANIMALS: A FACTOR REANALYSIS OF TWO DATA SETS

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ABSTRACT: Factor analysis has commonly been used to infer the dimensions of animal temperament. However, the results were often complicated by large number of broad and situation-specific factors caused by low psychometric adequacy of the correlation matrices, undermining the assumptions of factor analysis. In this study I reanalyzed the data sets obtained by Royce, Poley & Yeudall (1973) and Gervai & Csányi (1985) including, however, only the variables with high correlations (multiple $R^2 > 0.3$) and psychometric adequacies (Kaiser-Meyer-Olkin measure > 0.5). This yielded more stable and simpler factor solutions than in the original studies. Specifically, even though the present reanalysis cannot rule out the existence of other temperament factors, it indicates that two general dimensions, Activity-Exploration and Fear-Avoidance, are present in such diverse species as mice and the paradise fish.

Individual differences in behavior are well known to everyone who works with animals of virtually any species. Some of the recent reviews (Budaev, 1997a,b; Clark & Ehlinger, 1987; Eysenck & Eysenck, 1985; Stevenson-Hinde, 1983; Wilson, Clark, Coleman & Dearstyne, 1994) emphasized the importance of studying integrated behavioral phenotypes and stable traits that are consistent over time and across situations, that is, temperaments and personalities. Within such a framework human and animal temperament is viewed as a system of stable dimensions which are directly unobservable and must be inferred from the observed behavior in various situations.

The problem of extracting general temperamental traits is closely linked to geometrical models in which individuals are represented as points or vectors in a multidimensional space. The principal

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methodological task here is to find some solution with a minimum number of most salient temperament dimensions. It is performed typically by means of factor analysis. Because a few general factors can account for a large number of variables, the application of factor analysis brings interpretability and parsimony into the data.

The current evidence indicates that two broad dimensions, namely, Activity-Exploration (incorporating such traits as exploration, stimulus-seeking propensity and sociability) and Fear-Avoidance (composed of shyness, fearfulness, anxiety and escape propensity) were systematically observed in various vertebrate species. This implies that common adaptive, neural and hormonal mechanisms may be involved (Royce, 1977; Budaev, 1997a,b). For example, it is tempting to suppose (Budaev, 1997a,b) that in humans the dimensions analogous to Approach and Fear-Avoidance may represent two major personality dimensions, Extraversion-Introversion and Neuroticism, which are known to have clear physiological background and high heritability.

However, the results of most analyses turned out to be often complicated, and in addition to these two factors involved additional ones lacking replicability (to note only a few references: Cattell & Korth, 1973 in dogs, Royce, Poley & Yeudall, 1973 in mice; Gerlai & Csányi, 1990 in fish; Cattell, 1973 in humans). This was, probably, because many of these studies were conducted to take as many different variables as possible sampled as widely as possible, to cover the whole "personality sphere" (see Cattell, 1973). In this tradition "only a few variables can ever justifiably be eliminated, and the need for this elimination must be strong" (Cattell & Korth, 1973, p. 17), even though one can potentially measure a literally infinite number of behavioral variables. A methodological criticism often arises, namely, that factoring an arbitrary collection of heterogeneous variables with the primary aim to "invent hypotheses" in some inductive way, is methodologically flawed (e.g. Eysenck & Eysenck, 1985). But in many exploratory studies there may simply be no feasible alternative and a potentially important facet of temperament can be overlooked if some variables are arbitrarily omitted.

However, a more serious problem with such sparse analyses is of a statistical nature. The "personality sphere" approach has been criticized on the ground that correlations between diverse, randomly sampled variables approach correlations between random deviates (Humphreys *et al*, 1969). The issue of simultaneous statistical inference (note that the number of individual correlations is proportional to the square of the number of variables in the matrix) is also obvious. Computing a

collection of multiple tests based on a particular fixed overall significance level results in a high probability that some tests are significant by chance alone (Wright, 1992). Furthermore, excessive error variance could inflate communalities and produce spurious factors (Armstrong & Soelberg, 1968; Horn, 1967). As Armstrong & Soelberg (1968) demonstrated, an ostensibly interpretable factor pattern matrix may be obtained through application of the principal component analysis to even a collection random normal deviates.

Many analyses can also suffer from inappropriate statistical analysis. As Zwick and Velicer's (1986) examination has shown, the most widespread rule of thumb to retain as many factors as their eigenvalues exceed unity, is extremely poor and "very likely to provide a grossly wrong answer", which "seems to guarantee that a large number of incorrect findings will continue to be reported" (p. 439). In fact, the Kaiser's root-one method often overestimates the number of factors (Revelle & Rocklin, 1979; Zwick & Velicer, 1986), and a few broad factors are typically found more replicable across studies than many narrow factors (e.g. Guilford, 1977; Saville & Blinkhorn, 1981). Thus, some of the previously defined numerous factors of temperament in animals may be entirely spurious.

A detailed examination and reanalysis is possible for the data sets obtained by Royce, Poley & Yeudall (1973) and Gervai & Csányi (1985), in which the raw correlation matrices are available. An additional advantage is that both are based on unusually large sample sizes (respectively 775 mice *Mus musculus*, and 120 paradise fish *Macropodus opercularis*). Yet, a closer inspection reveals that in both cases some definitely spurious factors were interpreted. In the original study of Royce *et al* one can find at least two clear examples. The factor 13 was identified by two variables, however, at the neighboring page (Table 1, p. 40) one sees that these variables were surely uncorrelated ($r = -0.043$; $p > 0.1$ unadjusted for multiple tests); another example is the factor 15, also composed of equally unrelated variables. The factors containing one or more variables which do not correlate significantly (without adjustment for multiple inference) with other variables may also be found in the principal component solution of Gervai & Csányi (1985).

The aim of the present investigation was to reanalyze the correlation matrices of Royce, Poley & Yeudall (1973) and Gervai & Csányi (1985). Reanalysis of the existing data set provides a significant advantage over a collection of new data. One can hypothesize (see above) that two relatively independent factors would appear in both

cases, although of course additional factors cannot be ruled out. The measures of exploratory behavior and activity would correlate together and form the Activity-Exploration dimension whereas the measures of fearfulness would make up the Fear-Avoidance factor. This reanalysis is also interesting because neither Royce *et al* (1973) nor Gervai & Csányi (1985) hypothesized any structure, and variable selection was fully agnostic.

METHOD

The behavioral tests and measures are described in the original studies of Royce *et al* (1973) and Gervai & Csányi (1985), so only a brief account is provided here. Royce *et al* (1973) tested 775 mice of several strains in 12 tests presumed to measure their emotionality. Forty two variables were recorded in total including: avoidance conditioning, individual emergence and removal from a small cylindrical cage, activity wheels, open field test, straightway, platform on an elevated pole, emergence from dark into light and from light into dark, food goal-box test, circular activity with and without bell, and underwater swimming. Gervai and Csányi (1985) tested 120 paradise fish of three strains in three tests (restricted novel environment, approach to a novel object, emergence from a shelter and open field test). Unlike Royce *et al* (1973), who recorded arbitrary behavioral measures in the tests, Gervai and Csányi (1985) recorded elements of the natural ethogram of the paradise fish including; freezing, escape, air-gulping, moving, creeping, and approaching a novel object (this allows a direct quantitative comparison of temperament factors in the paradise fish with those identified in the guppy *Poecilia reticulata*, Budaev, 1997b). Both Royce *et al* (1973) and Gervai and Csányi (1985) factor-analyzed total correlation matrices, with all strains collapsed. For continuity, the same nomenclature as in the original papers is used for the behavioral measures.

The correlation matrices presented in the papers of Royce *et al* (1973) and Gervai and Csányi (1985) were entered into a computer and checked for errors. To estimate the degree to which components of the correlation matrix shared common variance, the Bartlett's sphericity test and the overall Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) were computed and the off-diagonal elements of the anti-image covariance matrix (Dziuban & Shirkey, 1974) were examined. Separate KMO indices were computed for each variable to assess their individual

factoring adequacy. Computation of the KMO index is desirable because a particular variable may have a high correlation with another variable, but still have poor adequacy, grossly falling out of the general pattern (e.g. if this is a chance correlation). Variables with $KMO < 0.5$ are likely to impair the factor solution and should be removed; no meaningful factors can be extracted if the overall value of KMO is smaller than about 0.5 since the correlation matrix approaches a random matrix (see Dziuban & Shirkey, 1974).

To identify unique uncorrelated variables, values of the squared multiple correlation coefficient (R^2) were examined for each variable. Then, the KMO indices for each variable were computed and those with $KMO < 0.5$ were excluded. The resulting subsets of variables were subjected to the final factor analysis. The multiple R^2 were used as initial estimates of communalities. The MINRES approach (in which the initial estimates of factor loadings are adjusted iteratively to minimize the residual sum of squares) was used for factor extraction, and the factor pattern matrix was rotated according to the normalized Varimax criterion (Wherry, 1984). Several other methods of extraction and rotation were also tried which yielded virtually identical results. To assess the number of factors inherent in the data, four different tests were employed: the Cattell's scree-plot, the Kaiser's rule to retain only factors with eigenvalues greater than unity (Wherry, 1984), the Revelle & Rocklin's (1979) Very Simple Structure (VSS) method, and the approach based on parallel analysis of simulated data (PA, see Zwick & Velicer, 1986), involving 100 random samples in each case. The tests showed no gross discrepancies.

Finally, a direct comparison of temperament factors identified in the paradise fish in the data of Gervai & Csányi (1985) with those determined in the guppy in a recent study (see Budaev, 1997b) was performed. Ahmavaara (Wherry, 1984), Tucker, Pearson and Kaiser-Hunka-Bianchini (KHB) factor comparison coefficients were computed for particular pairs of factors, as well as the KHB mean solution cosine for the overall agreement (Barrett, 1986). It was desirable to compute several independent indices based on different underlying assumptions (see Barrett, 1986).

RESULTS

The overall level of absolute off-diagonal correlation coefficients within the matrix of Royce *et al* (1973) was very low (very high

proportion of essentially zero correlations), possibly caused by low ecological validity of the arbitrary behavioral variables. In contrast, the correlations within the matrix of Gervai and Csányi (1985) were distributed bimodally with a good proportion of nonzero correlations (note that variables were represented by elements of the natural species' ethogram). The distribution of the multiple correlation coefficients in both cases was multi-modal (Figure 1) making it possible to establish a reasonable cut-off value for discarding poorly correlated variables. In the data of Royce *et al* (1973) it was 0.3 (the first gap, see Figure 1) while in the data of Gervai and Csányi (1985), it was 0.5.

While having relatively large multiple R^2 values (0.4-0.7), the four variables of weight at 40, 62 and 67 days (1, 35, 42) and sex (2), were also excluded from the final analysis of the data of Royce *et al* (1973). This was because they formed a separate well-defined factor (without salient loadings by the behavioral measures) and were considered of not much importance theoretically (see Cattell & Korth, 1973 for a similar

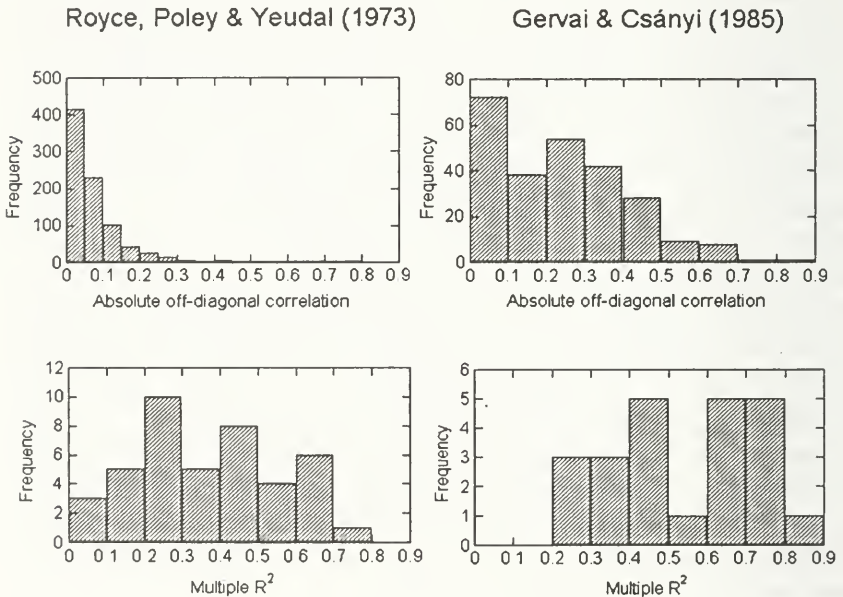


Figure 1. The analysis of the correlation matrices. Upper row, the distribution of individual correlation coefficients within the correlation matrices of Royce *et al* (1973) (left) and Gervai & Csányi (1985) (right). Lower row, the distribution of multiple correlation coefficients (squared values) in the data sets of Royce *et al* (left) and Gervai & Csányi (right).

unitary "body size" factor in dogs, and Budaev, 1997b for a report of no relation between temperament and size in a fish). However, the measures of sampling adequacy were computed including as well as excluding these variables.

As Table 1 shows, in both Royce *et al* (1973) and Gervai and Csányi (1985) data sets, the procedure of variable reduction led to an improvement of the overall KMO measures of sampling adequacy. Not surprisingly, exclusion of the well-identified factor containing weight and sex variables reduced it in the data of Royce *et al* (1973). Other measures of sampling adequacy (Table 1) revealed similar results, although in the Royce *et al* (1973) data the proportion of nonzero anti-image covariances increased. Thus, the reduced correlation matrices were more appropriate for factoring.

Table 1. Effect of the exclusion of variables on the measures of sampling adequacy. Data set of Royce *et al* analysed A, with and B, without the weight and sex variables; df, equivalent to the number of correlations in the Bartlett's test; χ^2 , from Bartlett's sphericity test, $p < 0.001$ for all values; KMO, Kaiser-Meyer-Olkin measure; %, percentage off-diagonal anti-image covariances > 0.09 .

	Data set analysed		df	χ^2	KMO	%
Complete Matrix	Royce, Poley & Yeudall (1973)	A	861	9051	0.62	6.62
		B	703	6919	0.58	7.97
	Gervai & Csányi (1985)		253	1334	0.78	16.21
Reduced matrix	Royce, Poley & Yeudall (1973)	A	153	5083	0.69	15.03
		B	91	3337	0.65	20.88
	Gervai & Csányi (1985)		66	897	0.82	12.12

Reanalysis of the data by Royce et al (1973)

Three factors with eigenvalues greater than unity appeared, the VSS index also reached its maximum for the three-factor solution, but the PA method indicated four factors. Although a simulation study by Zwick & Velicer (1986) have found that the PA method is the most accurate in principal component analysis, it is not so in factor analysis (Crawford & Koopman, 1973). Revelle & Rocklin (1979) have also observed that the Montanelli & Humphreys's (1976) procedure based exactly on its logic may show significant overestimation if

communalities and factoring adequacy are low, as it was the case in this study. Additionally, there is a strong ground to discard poorly defined factors retained by the PA method (Zwick & Velicer, 1986). Thus, three factors were extracted.

The rotated factor pattern is presented in Table 2. The first factor is rather easy to interpret, as it is made of the latency to enter the swim way (40), the latency to enter an opaque pipe from an open box (29), the latency to traverse the swim way (41), and has also minor loadings by cell urination (25) and the latency to descend from a 34-inch-high platform (20). Thus, it is likely to reflect a motivation to escape and fearfulness. The second factor is also easily interpretable and, in fact, it closely corresponds to the Motor Discharge factor identified by Royce *et al* (1973). Thus, the first two factors could really represent the Fear-Avoidance and Activity-Exploration, as hypothesized.

Table 2. Varimax-rotated factor loadings: Royce, Poley & Yeudall (1973) data; ** salient loadings (> 0.5); * lower but interpretable loadings (0.3-0.5)

Variables	Factor 1	Factor 2	Factor 3
Open field latency (10)	-.06	.64**	.06
Open field activity (11)	.00	-.79**	.12
Open field penetration (12)	-.10	-.57**	-.09
Straightway latency (15)	-.05	.39*	.32*
Straightway activity (16)	-.09	-.48*	-.13
Latency to leave the platform, pole (19)	.02	.25	.63**
Latency to descend the platform, pole (20)	.42*	.16	.31*
Defecation, pole (21)	.12	.06	.83**
Urination, cell (25)	.47*	-.01	-.06
Hole defecation (27)	.19	.02	.27
Pipe entrance, trial 1 (29)	.63**	.03	-.01
Pipe emergence, trials 2, 3, 4 (32)	.06	-.01	.59**
Underwater swimming, entrance (40)	.76**	-.00	.15
Underwater swimming, latency to traverse (41)	.57**	.02	.27
Eigenvalue	2.61	1.67	1.18
Variance accounted for (%)	18.65	11.94	8.40

The third factor, explaining 8% of variance, is difficult to interpret as it is composed of pole defecation (21), the latency to leave the elevated platform (pole) (19), the latency to emerge from an opaque pipe into the goal-box with several food pellets on trials 2, 3 and 4 (when the animal has already learned that food may be found there) (32), and has also minor loading by (also elevated) straightway latency

(15) and the latency to descend the platform (pole) (20). Although it seems to represent an unusual admixture of fear of an elevated platform and food motivation, it cannot be simply neglected.

However, an inherent two-dimensionality of the data was revealed when 4 (indicated by the PA technique; also a small elbow appeared on the scree plot after this factor) or 5 factors were extracted and submitted to the Wherry (1984) hierarchical rotation procedure. Two clear second-order factors emerged which were almost identical in terms of factor loadings to the above Factor 1 and Factor 2 (Tucker congruence coefficients = 0.96 and 0.83, respectively; Pearson correlation coefficients = 0.95 and 0.91, respectively).

Reanalysis of the data of Gervai & Csányi (1985)

Twelve behavioral variables were factor-analyzed (all variables with multiple $R^2 > 0.5$ had also the $KMO > 0.5$). Two factors with eigenvalues greater than unity appeared (Table 3), and both VSS and PA technique also revealed two factors. However, the scree-test indicated only one factor and in oblique rotations the factors were correlated, even though their pattern was virtually identical to the Varimax. Two factors were retained as indicated by the more reliable PA and VSS approaches (Revelle & Rocklin, 1979; Zwick & Velicer, 1986). Additionally, the scree test applied in a separate analysis of only marker variables (loadings > 0.7) clearly indicated two factors. These two factors were replicable (see below) and the correlation between them may have been caused by the large number of variables loading on the first factor and small number of variables uniquely identifying the second factor.

The first factor has salient loadings by the frequency of approach to the novel object (a rotating disk) (APF), the time spent near it (APD), latency to emerge from a shelter (in fact, a start-box, EML), air-gulping in the novel object test (AAG), air-gulping latency in a novel environment (AGL), the time spent freezing in a restricted environment (a white plastic dish) (FRD). The first factor is also loaded to a lesser degree by air-gulping duration (RAG) and freezing frequency (FRF) in a restricted space and air-gulping in a novel environment (A-G) (Table 3). Hence, it could be interpreted in terms of exploratory behavior and activity. The second factor has major loadings by freezing (FRZ), escape (ESC), air-gulping (A-G) in a novel environment and air-gulping in the restricted space (RAG). It also has minor loadings by air-gulping in the novel object test (AAG) and freezing in the restricted

space (FRD and FRF). Thus, the second factor may reflect fear motivation and the tendency to escape. That air-gulping contributed to the fear factor, especially in a potentially dangerous novel environment, would be adaptive. That is, a fish overtly swimming near the surface in presence of a dangerous stimuli will expose itself to a high risk. The fact that freezing was related to both factors agrees with the earlier evidence (Gerlai & Hogan, 1992; Budaev, 1997b) that this behavior may reflect both excessive fear and/or a mere inactivity or a relaxed state. Thus, the data obtained by Gervai & Csányi (1985) may also indicate the presence of the two major dimensions.

This two-factor pattern is almost identical to that obtained in the guppy, *Poecilia reticulata* (Budaev, 1997b). The factor similarity coefficients are remarkably large for both factors (Table 4). Thus, the factors are replicable, even in spite of differences in species ecology and environmental conditions during testing.

Table 3. Varimax-rotated factor loadings from data of Gervai & Csányi (1985). ** salient loadings ($p > 0.5$); * lower but interpretable loadings ($p = 0.3-0.5$).

Variables	Variable Code	Factor 1	Factor 2
Freezing duration, restricted space	FRD (1)	-0.56**	-0.39*
Air-gulping, restricted space	RAG (2)	0.48*	0.60**
Freezing frequency, restricted space	FRF (3)	-0.45*	-0.31*
Novel object approach frequency	APF (5)	0.81**	0.19
Air-gulping, novel object approach	AAG (6)	0.63**	0.47*
Novel object approach duration	APD (7)	0.77**	0.14
Latency to emerge from shelter, novel env.	EML (8)	-0.75**	-0.28
Air-gulping latency in a novel environment	AGL (11)	-0.61**	-0.16
Escape attempts in a novel environment	ESC (12)	0.13	0.73**
Swimming in a novel environment	SWI (13)	0.33*	0.25
Freezing in a novel environment	FRZ (21)	-0.19	-0.83**
Air-gulping in a novel environment	A-G (22)	0.38*	0.70**
Eigenvalue		5.37	1.03
Variance accounted for (%)		44.79	8.62

Table 4. Comparison of the two temperament factors identified in the paradise fish (Gervai & Csányi, 1985) and guppy (Budaev, 1997b); *, KHB mean solution cosine.

Factor of temperament	Factor similarity coefficient			
	Ahmavaara	Tucker	Pearson	KHB
Activity-Exploration	0.90	0.90	0.90	0.95
Fear-Avoidance	0.90	0.89	0.89	0.95 (0.94*)

DISCUSSION

In this paper, the mice data of Royce, Poley & Yeudall (1973) and the paradise fish data of Gervai & Csányi (1985) were reanalyzed. By eliminating uncorrelated variables it was possible to achieve much simpler factor solutions than in the original studies. The present results indicate the existence of two general dimensions of temperament in such diverse species, being Activity-Exploration and Fear-Avoidance. These factors were perfectly replicable across studies involving two fish species with different ecologys, even though the testing environments were obviously not identical. Of course, this does not mean that these are the only dimensions of temperament. Additional factors may appear if different tests and variables were used, as well as if not all weakly correlated variables were excluded from the analysis. None the less, the present analysis indicates that Activity-Exploration and Fear-Avoidance tend to be the most general, stable and replicable factors.

Finally, it is curious to note that a similar reduction of an initially very complicated factor structure occurs in the area of human personality studies. For example, Cattell (1973) identified as many as sixteen basic dimensions of personality. However, several recent studies failed to establish any replicability of the Cattell's 16PF. No one has been able to identify more than seven factors in the scales that were the basis of the whole system, and even these provided clear indication of the Extraversion and Neuroticism (Barrett & Kline, 1980; McKenzie, 1988; Saville & Blinkhorn, 1981) as well as the three other dimensions of the Big Five model of personality (see Digman, 1990 for a review).

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REFERENCES

- Armstrong, J.S., & Soelberg, P. (1968). On the interpretation of factor analysis. *Psychological Bulletin*, 70, 361-364.
- Barrett, P. (1986). Factor comparison: An examination of three methods. *Personality and Individual Differences*, 7, 327-340.
- Barrett, P., & Kline, P. (1980). The location of superfactors P, E, and N within an unexplored factor space. *Personality and Individual Differences*, 1, 239-247.
- Budaev, S.V. (1997a). The dimensions of personality in animals: The comparative and evolutionary framework. In M. Taborsky & B. Taborsky (Eds.) *Advances in Ethology*, Contributions to XXV International Ethological Conference, Vienna, Austria, 20-27 August 1997 (vol. 32, p. 90). Berlin: Blackwell Wissenschafts-Verlag (Abstract).
- Budaev, S.V. (1997b). "Personality" in the guppy (*Poecilia reticulata*): A correlational study of exploratory behavior and social tendency. *Journal of Comparative Psychology*, 111, 399-411.
- Cattell, R.B. (1973). *Personality and mood by questionnaire*. San Francisco: Jossey-Bass.
- Cattell, R.B., & Korth, B. (1973). The isolation of temperament dimensions in dogs. *Behavioural Biology*, 9, 15-30.
- Clark, A.B., & Ehlinger, T.J. (1987). Pattern and adaptation in individual behavioral differences. In P.P.G. Bateson & P.H. Klopfer (Eds.) *Perspectives in ethology* (vol. 7, pp. 1-47). New York: Plenum Press.
- Crawford, C.B., & Koopman, P. (1973). A note on Horn's test for the number of factors in factor analysis. *Multivariate Behavioral Research*, 8, 117-125.
- Digman, J.M. (1990). Personality structure: Emergence of the five-factor model. *Annual Review of Psychology*, 41, 417-440.
- Dziuban, C.D., & Shirkey, E.S. (1974). When is a correlation matrix appropriate for factor analysis? Some decision rules. *Psychological Bulletin*, 81, 358-361.
- Eysenck, H.J., & Eysenck, M.W. (1985). *Personality and individual differences. A natural science approach*. New York: Plenum Press.
- Gerlai, R., & Csányi, V. (1990). Genotype-environment interaction and the correlation structure of behavioral elements in paradise fish (*Macropodus opercularis*). *Physiology and Behavior*, 47, 343-356.
- Gerlai R., & Hogan J.A. (1992). Learning to find the opponent: an ethological analysis of the behavior of paradise fish (*Macropodus opercularis*) in intra- and interspecific encounter. *Journal of Comparative Psychology*, 106, 306-315.
- Gervai, J., & Csányi, V. (1985). Behavior-genetic analysis of the paradise fish, *Macropodus opercularis*. I. Characterization of the behavioral responses of inbred strains in novel environments: A factor analysis. *Behavior Genetics*, 15, 503-519.
- Guilford, J.P. (1977). The invariance problem in factor analysis. *Educational and Psychological Measurement*, 37, 11-19.
- Horn, J.L. (1967). On subjectivity in factor analysis. *Educational and Psychological Measurement*, 27, 535-538.
- Humphreys, L.G., Ilgen, D., McGrath, D., & Montanelli, R. (1969). Capitalization on chance in rotation of factors. *Educational and Psychological Measurement*, 29, 259-271.
- McKenzie, J. (1988). Three superfactors in the 16PF and their relation to Eysenck's P, E, and N. *Personality and Individual Differences*, 9, 843-850.

- Montanelli, R.G.Jr., & Humphreys, L.G. (1976). Latent roots of random data correlation matrices with squared multiple correlations on the diagonal: A Monte Carlo study. *Psychometrika*, *41*, 341-348.
- Revelle, W., & Rocklin, T. (1979). Very simple structure: An alternative procedure for estimating the optimal number of interpretable factors. *Multivariate Behavioral Research*, *14*, 403-414.
- Royce, J.R. (1977). On the construct validity of open-field measures. *Psychological Bulletin*, *84*, 1098-1106.
- Royce, J.R., Poley, W., & Yeudall, L.T. (1973). Behavior genetic analysis of mouse emotionality: I. Factor analysis. *Journal of Comparative and Physiological Psychology*, *83*, 36-47.
- Saville, P. & Blinkhorn, S. 1981. Reliability, homogeneity, and the construct validity of 16PF. *Personality and Individual Differences*, *2*, 325-333.
- Stevenson-Hinde, J. (1983). Individual characteristics: a statement of the problem. Consistency over time. Predictability across situations. In R.H. Hinde (Ed.) *Primate social relationships: An integrated approach* (pp. 28-34). Oxford: Blackwell.
- Walsh, R.N., & Cummins, R.A. (1976). The open-field test: a critical review. *Psychological Bulletin*, *83*, 482-504.
- Wherry, R.J. (1984). *Contributions to correlational analysis*. New York: Academic Press.
- Wilson, D.S., Clark, A.B., Coleman, K., & Dearstyne, T. (1994). Shyness and boldness in humans and other animals. *Trends in Ecology and Evolution*, *9*, 442-446.
- Wright, S.P. (1992). Adjusted P-values and simultaneous inference. *Biometrics*, *48*, 1005-1013.
- Zwick, W.R., & Velicer W.F. (1986). Comparison of five rules for determining the number of components to retain. *Psychological Bulletin*, *99*, 432-442.