Spearman's *g*, the verbal-performance balance, and brain processes: the Lynn–Vernon debate

HELMUTH NYBORG and BO SOMMERLUND

International Research Center for Psychoneuroendocrinology, Institute of Psychology, University of Aarhus, Aarhus, Denmark

Summary—Lynn [(1987) *Personality and Individual Differences, 8,* 813–844] recently treated individual, sex, and race differences in intelligence in terms of an orthodox British psychometric tradition. Verbal (V) and visuo-spatial (S) abilities constitute, according to this line, bipolar factors but are inversely related in samples homogenous with respect to Spearman's general factor, *g*. Lynn's basic assumption was that the common positive V/S correlation in populations with heterogenous *g* reflects one physiological brain process, whereas the negative V/S correlation in populations homogenous for *g* has another brain basis. Vernon [(1990) *Personality and Individual Differences, 11,* 751–754] disagreed and set out to demonstrate, that the negative V/S correlation in samples homogenous for *g* is a statistical artifact. Lynn was not convinced by Vernon's demonstration, and found that Vernon's data provided strong support for his dual brain process theory. The present study demonstrated that the negative V/S association is a purely formal function of control for *g*, and illustrated why the negative V/S correlation must change from strongly negative to zero to moderately positive as *g* heterogeneity increases. The analysis suggests that psychometrics cannot prove brain theories of abilities, and that future studies of individual, sex, and race differences better focus more directly on individual brain development.

INTRODUCTION

Burt (1949) and Vernon (1950; see also Smith, 1964, p. 81) argued, in line with an orthodox British position, that verbal and visuo-spatial (V/S) abilities together constitute a bipolar factor, the S and V components being inversely related, apart from Spearman's *g* (Spearman 1904). Lynn (1987) used this idea to explain V/S differences in abilities between males and females, and also the strong S abilities in Mongoloid populations, which contrast their relatively weak V abilities. Lynn, acknowledging the common tendency in normal populations for positive correlations between most ability sub-tests, as long as they are heterogenous with respect to *g*, hypothesized that one general physiological brain process explains the positive V/S correlations. Lynn further suggested that, the tendency for negative correlations between V and S abilities will ordinarily be obscured by the operation of Spearman's *g*, which is responsible for pulling all abilities together into positive correlations. To explain the negative correlation between V/S abilities Lynn postulated the existence of a second physiological brain process. Lynn thus saw the inverse V/performance (P) balance as a kind of trade-off between the amount of cerebral cortex devoted to the V and S abilities, respectively. As adult brain size is fixed within the skull, allocating more cortical substance to V abilities simply implies that there will be less available for S analyses. Lynn's idea was, in other words, to explain positive V/S correlations by one brain process, and negative V/S correlations by other brain processes restrained by limited capacity for concomitant V and S processing. While acknowledging that it is not yet possible to specify the precise nature of these brain processes, Lynn recommended two different psychometric methods for examining the otherwise obscured negative V/S relationship: (1) by statistically keeping Spearman's *g* constant or, (2) by studying the ability pattern in groups homogenous for *g*.

Vernon (1990) did not appreciate Lynn's approach and set out to prove that it was wrong. Based on a re-analysis of some earlier data Vernon, in essence, illustrated numerically what happens to the V/S balance under various conditions of partialling out *g*. He showed for example that, the better *g* is controlled, the closer the V/S correlation will be to a perfect − 1. Conversely, the more heterogeneous the sample is with respect to *g*, the less negative will be the V/S correlation. Vernon further demonstrated that the initially strongly negative correlation in a homogenous sample gradually sinks to zero with increasing heterogeneity, to rise again to about 0.3 in his total sample of 100 people with WAIS full scale scores ranging from 110 to 165. Vernon sees all this as a statistical artifact, owing to the manner in which *g* is operationally defined and derived. Lynn (1990) was not persuaded by Vernon's critique, however. He still found his own data empirically valid and added that Vernon's analysis provided the clearest corroboration hitherto available for a dual brain process theory of intelligence. In doing so, Lynn referred to Popper's principle of falsification. There was no reason to accept Vernon's claim, that the negative partial V/S correlation was merely a statistical artifact, because the observation could in principle fall prey to falsification.

The Lynn–Vernon debate raises questions about the development of individual, sex, and race differences in ability patterning. Are, for example, the repeated observations of a negative V/S correlation with constant *g* and the tendency for a female V/S and a male S/V balance artifacts or empirical facts? Why keep *g* constant, anyway? Is the psychometric partial correlation coefficient approach appropriate at all in the search for the brain base of abilities? Can psychometrics determine whether we need more than one brain process to explain available observations? These questions are important because much research on the concept of intelligence is based on the idea of a common factorial or first order denominator for abilities.

This paper addresses the questions by determining whether Vernon is right that the negative V/S correlation and the change in sign and size of the coefficient follows from the way *g* is defined. We then call attention to a number of

requirements that must be met in order to discover more efficient ways of studying details of the development of individual, sex, and race differences and brain–ability relationships.

The first task was to determine by way of geometrics, whether positive and negative V/S correlation coefficients simply reflect formal characteristics of the way g is defined. For clarity of presentation we disregarded the fact that V and S may each represent the additive sum of several sub-scale scores, and concentrated more narrowly on a few V items and on the S sub-scale score of the total P score. Given that $g = V + S$, the questions were: Why is the correlation between V and S always close to -1 with narrow g, and does this rule of an inverse relationship apply at all levels of constant g?

To answer both questions, first consider a group of Ss, each with $g = 165$. Obviously, a "Perfect inverse relationship—rule" applies to all S at this level of constant g. For example, S A obtained his overall $g = 165$ by obligatory addition to his V sub-test score of 82.5 and his S sub-test score of 82.5. S B likewise obtained a $g = 165$, but this time by addition of the relatively low $V = 72.5$ and the relative high $S = 92.5$. Finally, S C got his $g = 165$ as a sum of high $V = 92.5$ and low $S = 72.5$. Second, the "Perfect inverse reationship—rule" also applies within groups of Ss with $g = 110$, 144, or any other constant g value. The essence of the rule is that any upward (or downward) variation in V (or in S) must per definition be compensated for by an opposite symmetrical downward (or upward) change in the value of S (or V) for all Ss with identical g, and the compensation must, by defining g as the sum of V and S, be of exactly the same size; only signs are reversed. This rule fully explains the perfect -1 V/S correlation seen under each condition of maximal restriction of g.

Vernon (1990) suspected that, the extent of heterogeneity of g determines the size and the sign of the V/P correlation. To see whether this was the case, he divided his total sample of 100 Ss into 21 sub-samples characterized by increasingly higher full-scale scores. By inspecting the various partial correlations among selected WAIS sub-test scores in the sub-samples it became evident, that the most homogeneous sub-sample 21, a group of 11 Ss each with a full scale score 165 or above (i.e. an IQ at or above 133) obtained a negative correlation of about -0.8 between information (a V-item) and Block Design (a S/P-item), as well as between Vocabulary (another V-item) and Block Design. The correlation among intra-scale V-items, such as Information and Vocabulary, remained positive across all variations in the heterogeneity of g. As samples with increasingly lower g's were included in the target group, making it more heterogeneous with respect to g, the negative V/P correlation dropped correspondingly, and eventually reached zero when the target group included sub-samples 11–21. This target sample included about half the original 100 Ss, and nobody in the group obtained a g-value below 144. A further reduction of homogeneity, by incorporating Ss with still lower g's, gave a positive V/P correlation. When all 100 Ss were included in the target sample, the correlation reached an optimum $r = 0.3$. As expected, the correlation between sub-scale V scores was positive and did not vary as a function of changing the homogeneity of g. This numerical demonstration, that homogenizing g inevitably results in a large negative V/P sub-tests correlations, forced Vernon to conclude that we are dealing here with an inevitable consequence of the manner by which g is derived.

Graphical examination of Vernon's data illustrates that there is one and only one way in which the sign and size of the sub-scale correlation can change, as long as the total score, g, is defined as the additive sum of sub-scale scores, and the homogeneity factor is varied. The negative V/P correlation with constant g is simply a special case of a general rule. Vernon's sample 21 is highly restricted with respect to g; it contains 11 Ss with full scale scores equal to or above 165. Any variation in V must by definition be exactly and inversely compensated for by changes in P, or vice versa. The strong restriction on g means that the data points (V, P) closely collect in an oblongish swarm around the negatively tilted line. This reflects the negative -0.8 V/P correlation in sample 21. The 52 Ss in sub-samples 11–21 are all characterized by a full scale score of 144 or above. The relaxation from strict homogeneity of g forces the V/P correlation towards zero and the data points (V, P) collect in an almost circular swarm. When more Ss are added to the target group, as in the total sample 1–21, the variability of g reaches its maximum and the V/P correlation becomes moderately positive (0.3) and the data points (V, P) collect in an oblongish swarm around a positively tilted line. In other words, an ordinary scattergram makes it obvious that the changes in the size and sign of the V/P correlations reflect obligatory changes in the actual distribution of data as a direct function of the homogeneity of g.

DISCUSSION

The results of our geometrical analyses of the V/S correlation under various conditions of g homogeneity line up with the outcomes of the numerical analyses by Vernon (1990). Both kinds of analyses show that with strict control for g, the relationship between V and S (or P) must of necessity approach -1. Both analyses further indicate that, as the sample becomes increasingly heterogeneous with respect to g, the sign of the V/S correlation must change from negative over zero to positive. This is not an artifact, but inevitably follows from the way g is defined and restricted. The implication is, that the partial correlations approach to g has no explanatory relevance at all. A result, that follows from its own formal definition, can reveal neither causes nor effects in the real world. We, therefore, conclude that the psychometric approach does not reveal the nature of the relationships between the brain and its abilities. As a secondary result, the geometrical analysis proves that there is no way to falsify the negative V/S relationship obtained by the partial g approach.

The most important question remains, however. Lynn (1978, 1987, 1990), Vernon (1990), and many others agree, that the brain must be of central importance for understanding the observed individual, sex, and race differences in abilities. So the essential question is whether there are better ways to probe their nature and causes? Future studies undoubtedly will differ from the classical psychometric approach in a number of important ways, as seen in recent studies by for example Barrett, Daum and Eysenck (1990), Jensen and Sinha (1991), Vernon and Mori (1990), and Willerman, Schultz, Rutledge and Bigler (1991). We must ask of the new studies, that their results must be potentially falsifiable, and that their focus will be closer to the brain than computation of first order or primary factors, or partial correlations are. The classical psychometric approach has served us well in the past, but fresh studies will probably converge on the ontogenetic unfolding of brain structures, and on the efficacy of structures and processes in a systematic attempt to relate brain with patterns of abilities. We must further ask of the alternatives, that they be able to deal efficiently with different individuals, rather than primarily with individual differences, averages, and variances (Nyborg, 1987), and that they monitor ability development over time in order to detect the endogenous and exogenous factors of person-specific importance for the unfolding of abilities. There may be no other way to derive genuinely general theories about brain–ability development (Nyborg, 1977).

Obviously, none of these propositions are new, and each of them raises a host of further questions. It is difficult to point out theoretically where to look for relevant causes, effects, and conditions, and then to methodologically operationalize their mechanisms and describe changes in an individualized developmental perspective. Where and when in the complex

human system can we expect to find causes of sufficient simplicity to be clearly discernable from other causes, and yet of sufficient power and directionality to be useful in understanding the nuts and bolts of brain–ability relationships across individuals? How to construct cause–mechanisms–effect models of brain development–abilities that, at one and the same time, make sense in terms of evolutionary theory but nevertheless are straightforwardly falsifiable given only ontogenetic data? Is it possible at all to construct a model that accounts, if not in detail then in outline, for the data on individual, sex, and race differences in V/S (Lynn, 1978; Vernon, 1982), a model that also explains the observation of a very dynamic intra-personal inverse relationship between V and S in menstruating women (Hampson, 1986; Hampson & Kimura, 1988; Nyborg, 1979) within the same framework? A forthcoming paper examines whether the General Trait Covariance-Andro-gen/Estrogen model (Nyborg, 1979, 1981, 1983, 1984, 1988, 1990, Nyborg & Nielsen, 1981) meets the above requirements (Nyborg, submitted). An attempt is made here to generate a coherent frame of reference for the immensely complex developmental phenomena of brain–ability relationships in terms of an analysis of the dynamic interplay between genes, sex hormones, and environment. Initial application suggests that the model account for the developmental time-table for the appearance of individual and sex differences in V and P (or S), and may even explain some aspects of covariant sex, body, brain, ability, and personality differentiation in addition to the inverse menstrual cycling of V and P. Best of all, though, the model is falsifiable.

REFERENCES

Barrett, P. T., Daum, I. & Eysenck, H. J. (1990). Sensory nerve condition and intelligence: a methodological study. *Journal of Psychophysiology, 4,* 1–13.

Burt, C. (1949). The structure of the mind: A review of the results of factor analysis. *British Journal of Educational Psychology, 19,* 100–111, 176–199.

Hampson, E. (1986). Variations in perceptual and motor performance related to phase of the menstrual cycle. *Canadian Psychology, 27(2A),* 268.

Hampson, E. & Kimura, D. (1988). Reciprocal effects of hormonal fluctuations on human motor and perceptuo-spatial skills. *Behavioral Neuroscience, 102(3),* 456–459.

Jensen, A. R. & Sinha, S. N. (1991). Physical correlates of human intelligence. In Vernon, P. A. (Ed.), *Biological approaches to the study of human intelligence.* Norwood, NJ: Ablex.

Lynn, R. (1978). Ethnic and racial differences in intelligence: International comparisons. In Osborne, R. T., Noble, C. E. & Weyl, N. (Eds), *Human variation: The biopsychology of age, and sex.* NY: Academic Press.

Lynn, R. (1987). The intelligence of the Mongoloids: A psychometric, evolutionary, and neurological theory. *Personality and Individual Differences, 8,* 813–844.

Lynn, R. (1990). Negative correlations between verbal and visuo-spatial abilities: Statistical artifact or empirical relationship? *Personality and Individual Differences, 11,* 755–756.

Nyborg, H. (1977). *The rod-and-frame test and the field dependence dimension: Some methodological, conceptual, and development considerations.* Copenhagen: Dansk Psykologisk Forlag.

Nyborg, H. (1979). Sex chromosome abnormalities and cognitive performance. V: Female sex hormone and discontinuous cognitive development. Paper and handout presented to the symposium on "Cognitive studies" at the *Fifth Biennial Meeting of the International Society for the Study of Behavioural Development,* Lund, Sweden, June 25–29.

Nyborg, H. (1981). Hormonal correlates of spatial ability development. Paper presented at the *VIth Congress of The International Society for the Study of Behavioral Development,* Toronto, Canada, August.

Nyborg, H. (1983). Spatial ability in men and women: Review and new theory. *Advances in human research and therapy, Vol. 5., Monography Series* (pp. 39–140). Oxford: Pergamon Press.

Nyborg, H. (1984). Performance and intelligence in hormonally-different groups. In de Vries, G. J., de Bruin, J. P. C., Uylings, H. B. M. & Corner, M. A. (Eds), *Sex differences in the brain. Progress in brain research, Vol. 61* (pp. 491–508). Amsterdam: Elsevier.

Nyborg, H. (1987). Individual differences or different individuals? That is the question. *The Behavioral and Brain Sciences, 10,* 34–35.

Nyborg, H. (1988). Mathematics, sex hormones, and brain function. *The Behavioral and Brain Sciences, 11,* 206–207.

Nyborg, H. (1990). Sex hormones, brain development, and spatio-perceptual strategies in Turner's syndrome. In Berch, D. B. & Bender, B. G. (Eds), *Sex chromosome abnormalities and human behavior: Psychological studies* (pp. 100–128). Boulder, CO.: Westview.

Nyborg, H. (submitted). Individual and sex differences in covariant body, brain, ability, and personality development: The General Trait Covariance—Androgen/Estrogen model.

Nyborg, H. & Nielsen, J. (1981). Sex hormone treatment and spatial ability in women with Turner's syndrome. In Schmid, W. & Nielsen, J. (Eds), *Human behavior and genetics* (pp. 167–182). Amsterdam: Elsevier.

Smith, I. M. (1964). *Spatial ability: Its educational and social significance.* CA: Knapp.

Spearman, C. (1904). General intelligence, objectively determined and measured. *American Journal of Psychology, 15,* 201–293.

Vernon, P. E. (1950). *The structure of human intelligence.* New York: Wiley.

Vernon, P. E. (1967). Abilities and educational attainments in an East African environment. *The Journal of Special Education, 1(4),* 335–345.

Vernon, P. E. (1982). *The abilities and achievement of Orientals in North America.* New York: Academic Press.

Vernon, P. A. (1990). The effect of holding g constant on the correlation between verbal and nonverbal abilities: a comment on Lynn's "The intelligence of the Mongoloids ..." (1987). *Personality and Individual Differences, 11,* 751–754.

Vernon, P. A. & Mori, M. (1990). Physiological approaches to the assessment of intelligence. In Reynolds, C. R. & Kamphaus, A. W. (Eds), *Handbook of psychological and educational assessment of children: Intelligence and achievement.* New York, NY: Guilford.

Willerman, L., Schultz, R., Rutledge, J. N. & Bigler, E. D. (1991). *In vivo* brain size and intelligence. *Intelligence, 15,* 223–228.