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Divergent Validity and the Measurement of Processing Capacity

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Commentary on "Divergent Validity and the Measurement of Processing Capacity" by Steven Pulos

I do not disagree with most of the substantive conclusions that Steven Pulos draws, based on his reanalyses of Case and Globerson (1974) and Morra's (1994) data. My problem is with his epistemological presuppositions. He writes as if the classic epistemology of exploratory factor analysis is somewhat truer and more rigorous than the epistemology of developmental constructivism. In classical exploratory factor analysis a main semantic assumption is that the obtained factors are indexing causal determinants that can explain the matrix of correlations. However, if we look at what these factors actually are in terms of the operations involved in their extraction, factors appear instead as higher-order descriptive response variables: They represent components of covariation patterns among tests, in terms of subjects' own responses—relational "empirical invariants" or latent variables. Thus, even more clearly than correlations themselves, first-order factors represent quantified relations of equivalence among tests, in terms of the subjects' responses. One might concede that factors must then stand for *relations of coexistence* in the tests loading on them—relations among semantic/qualitative *facets* or aspects that coexist in tests loading on the same factor; these are facets that the tests share. But nothing in the technique of factor analysis tells us which these facets actually are.

To answer these questions, factor analysts have traditionally used phenomenology, often a home-grown variety, perhaps a naïve one. Factor analysts have not until recently (e.g. Frederiksen, Mislevy, & Bejar, 1993) been interested in subjective/rational task analysis—a form of applied phenomenology which, in combination with suitable developmental-process and individual-difference elements, lends itself to the semantic clarification of empirical tests. The hierarchical structure of factors proposed by classical factor analysts is predicated on the method of factor extraction, and implies

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that a *superordinate factor(s) is(are) present in the tests along with factors which in the method of extraction were extracted first*. A rotation to Thurstone's simple structure—the criterion used in rotations such as varimax and promax—consists in rotating factors around their origin until the number of zero loadings in the factor matrix has been maximised; and so each variable/test is loading on as few factors as possible. Thus, when an unrotated solution (or a higher-order general factor) is compared with a first-order rotated solution (or factor), the "shift is from factors maximising total variance to factors delineating separate groups of highly intercorrelated variables" (Rummel, 1970, p. 377). Rotation to simple structure transforms a "solution accounting for the variance of a variable by several factors to a solution accounting for this variance by one, or at most two, factors" (Rummel, 1970, p. 381). If we think of a test/variable as reflecting the subjects' reaction to the organised constellation of qualitative *facets* of all sorts that together constituted the test as actually scored, it should be apparent that what rotations do is change the semantics of each factor to approximate a *combination of facets* that, as combination, constitutes a processing *mental-strategy formula* (MS formula), that is, the MS formula of a collection of tests that are reacted to similarly (collinearly) by the subjects. Thus group/rotated factors are more complex semantically, in terms of the facets indexed, than are general/unrotated factors; and the same kind of argument shows that oblique solutions are similarly more complex and concrete semantically than orthogonal solutions. From this semantic perspective, the various factor-analytical solutions to the factor extraction problem represent qualitatively distinct and alternative viewpoints—different tools for inferring the semantics of tests in terms of facets. Further, all factor-analytical solutions index *latent variables*, that is, relational empirical variables defined in terms of patterns of coexistence (equivalence relations) among the subjects' responses to the tests or test items. One should not, as Pulos might, confuse this sort of *latent* variable with organismic theoretical constructs (such an M power) of a truly general nature—*hidden* organismic processes that can be applied across types of tests to improve performance irrespective of the (content, method, and strategy) variance found in the test in question. The theoretical construct M power, which Pulos also globally calls processing capacity (PC), is thus not a latent variable but a *hidden variable*. This semantic analysis of (exploratory) factor analysis suggests that hidden variables like M power should be expected to appear as "pure" variance only in the first factor of an unrotated factor solution or in a higher-order general-factor rotated solution. Rotated group-factor solutions, and even more so if they are oblique solutions, should present this M capacity variance mixed with other sources of variance (e.g. content, method, strategy). When Pulos takes issue with Morra's suggestion of using several measures to jointly index M power in

correlational studies, he may be treating the hidden construct M as if it were another psychometric latent variable. This is a common error among Developmentalists. However, theoretical (organismic) constructs, being hidden variables, require convergent operations, experimental-developmental designs, individual-difference-experimental designs, etc., to be fully demarcated empirically. Factor analysis can only be one line of research.

It is not surprising that oblique rotations of Case and Globerson's data and of Morra's data show a Gf/Gv factor in the tasks that index M power. Most of the measures currently available for this purpose involve either a visuo-spatial perceptual inference paradigm, or an information-processing working memory paradigm, or both. Because M power is a hidden variable, any task purported to measure M will necessarily involve other (content, method and strategy) facets as well. The lack of true orthogonality of an imputed rotated M factor with other rotated factors (such as visuo-spatial/general intelligence), does not necessarily weaken the validity of M measures; to think otherwise is to confuse the hidden variable M with a latent variable (such as a rotated group factor).

This kind of semantic confusion between hidden constructs and latent variables is very frequent among Developmentalists, even those who are constructivists. For instance, in his otherwise excellent work Morra (1994, p. 152) recommends, to facilitate the semantic interpretation of factors, that researchers make a "close inspection of correlations, with age partialled out". This curious but common mistake of partialling out age to clarify the semantics of correlations in tasks indexing M capacity, can be dispelled as follows. Because the organismic hidden construct M is theoretically said to model a maturational, *age-bound growth* of mental attentional resources in normal children, partialling out age from correlations among tests purported to index M capacity would theoretically exclude the very source of general-factor variance that in theory we ought to preserve. Indeed, partialling out age would have as effect to exclude (along with amount of experience—which also increases with age within a homogeneous sociocultural group) the source of variance which uniquely corresponds to M capacity, different from (albeit included into) MS formulas specific to different types of tasks. Item Response Theory would predict that, *if* the measures of M capacity were pure measures of M, partialling out age should cancel intercorrelation altogether. The sizeable residual correlations reported by Morra (1994) in Tables 2 and 4 are best interpreted as indexing MS formulas that are common within this set of M capacity tasks—the semantic information that rotated factors readily yield.

And how then can we empirically evaluate a hidden construct/variable such as M? The basic idea is to use convergent operations. This hypothetically deductive methodology can take many forms (e.g. de

Ribaupierre & Pascual-Leone, 1984; Johnson, Fabian, & Pascual-Leone, 1989; Pascual-Leone, 1970, 1978, 1994; Pascual-Leone & Baillargeon, 1994; Pascual-Leone & Sparkman, 1980). Morra (1994) gives an elegant illustration of this methodology by computing an ANOVA over the M scores from his various tasks using Tasks and Age as independent variables. He determines, not surprisingly, that both independent variables have main effects consistent with expectations. Nonetheless, he shows that the mean M scores for the different tasks are quite close, and the within subject's variance of these M scores is small. Thus, in spite of mental-strategy, method, and content differences among tests, the M capacity estimates of subjects are relatively invariant across tasks. This invariance speaks of a *general organismic factor*, manifested in all tests despite their differences. As Morra points out, this invariance justifies averaging the test scores to generate a more valid organismic M score. The existence of other more concrete (*group factor*) similarities, or differences, among these tests is no argument against this procedure. Pulos is in this regard mistaken.

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REFERENCES

Case, R., & Globerson, T. (1974). Field dependence and central computing space. *Child Development*, *45*, 772–778.

de Ribaupierre, A., & Pascual-Leone, J. (1984). Pour une integration des methodes en psychologie: Approaches experimentale, psychogenetique et differentielle. *L'Annee Psychologique*, *84*, 227–250.

Frederiksen, N., Mislevy, R.J., & Bejar, I.I. (Eds.) (1993). *Test theory for a new generation of tests*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Johnson, J., Fabian, V., & Pascual-Leone, J. (1989). Quantitative hardware-stages that constrain language development. *Human Development*, *32*, 245–271.

Morra, S. (1994). Issues in working memory and measurement: Testing for M capacity. *International Journal of Behavioral Development*, *17*, 143–159.

Pascual-Leone, J. (1970). A mathematical model for the transition rule in Piaget's developmental stages. *Acta Psychologica*, *32*, 301–345.

Pascual-Leone, J. (1978). Compounds, confounds and models in developmental information processing: A reply to Trabasso and Foellinger. *Journal of Experimental Child Psychology*, *26*, 18–40.

Pascual-Leone, J. (1994). An essay review of Halford's "An experimentalist's understanding of children". *Human Development*, *37*, 370–384.

Pascual-Leone, J., & Baillargeon, R. (1994). Developmental measurement of mental attention. *International Journal of Behavioral Development*, *17*, 161–200.

Pascual-Leone, J., & Sparkman, E. (1980). The dialectics of empiricism and rationalism: A last methodological reply to Trabasso. *Journal of Experimental Child Psychology*, *29*, 88–101.

Rummel, R.J. (1970). *Applied factor analysis*. Evanston, IL: Northwestern University Press.