Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Intelligence 34 (2006) 587 – 591
INTELLIGENCE

The cylindrical structure of the Wechsler Intelligence Scale for Children — IV: A retest of the Guttman model of intelligence

Arie Cohen [a,*], Catherine A. Fiorello [b], Frank H. Farley [b]

[a] Bar-Ilan University, Israel
[b] Temple University, United States

Received 29 November 2005; received in revised form 12 April 2006; accepted 27 May 2006
Available online 17 July 2006

Abstract

A previous study on the underlying structure of the Wechsler intelligence test (WISC-R; [Wechsler, D. (1974). Manual WISC-R: Wechsler intelligence scale for children—Revised. New York: Psychological Corporation]), using smallest space analysis (SSA) [Guttman, L., and Levy, S. (1991). Two structural laws for intelligence tests. *Intelligence*, 15, 79–103] had indicated a three-dimensional cylindrical solution. The first described level of abstract thinking (rule inferring, rule applying, rule following or new learning tasks), the second related to mode of representation (verbal, numeral, visual), while the third dimension related to output mode (oral, manual, or pencil and paper). In view of the appearance of the recent version of this test (WISC-IV; [Wechsler, D. (2003). Manual for the Wechsler Intelligence Scale for Children—Fourth edition. San Antonio, TX: The Psychological Corporation]), the purpose of the present study is to test Guttman's model of intelligence on the current version of the scale. Thus, the intercorrelation matrix of the WISC-IV subtests of the entire normative sample of 2200 children was submitted to SSA. This solution replicates Guttman and Levy three-dimensional cylindrical structure almost completely, and it offers further differentiation of the visual mode into geometric and pictorial modes and implies that the Block Design subscale relates to the "rule inferring" category. The Guttman model organization of the present solution provides an elegant description of the structure of intelligence and suggests the construction of new subscales for measuring different aspects of intelligence.

Keywords: Intelligence; WISC-IV; Guttman model

The pursuit of the underlying structure of intelligence has intrigued psychologists since the dawn of the previous century. The most common method of examining the underlying nature of a set of variables in general, and the subtests of an intelligence test in particular, is factor analysis. In fact, factor analysis was originally invented by Spearman (1904) in order to conceptualize the nature of intelligence. Its underlying assumption is that observed variables are the functions of latent variables called factors and its goal is to identify these factors. Indeed, most widely accepted models of intelligence today are based on factor analytic research (e.g. Cattell–Horn–Carroll Theory; McGrew, 1997). Factor analytic studies of cognitive abilities such as Carroll's meta-analysis yield a hierarchical structure, with *g* at the apex, an array of broad cognitive abilities underneath, and narrow abilities under those (Carroll, 1993).

The Wechsler scales, the most commonly used tests of intelligence, have traditionally been divided conceptually into verbal and non-verbal (performance) sections.

* Corresponding author. School of Education, Bar-Ilan University, 52900 Ramat Gan, Israel.
E-mail address: ariecohen40@hotmail.com (A. Cohen).

0160-2896/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.intell.2006.05.003

However, with the publication of the WISC-R, factor analyses revealed the presence of a third factor separate from the verbal and performance factors (Kaufman, 1979), calling into question the two-part model of intelligence. During the development of the WISC-III, therefore, an additional subtest was developed to attempt to clarify the factor structure of the test, leading to the emergence of four factors (Wechsler, 1991), though the venerable Verbal and Performance IQs remained. The most recent, fourth edition (WISC-IV; Wechsler, 2003) has embraced and expanded the four factors, leading to the abandonment of the Verbal and Performance dichotomy in favor of four scores: the *Verbal Comprehension Index* (Similarities, Vocabulary, Comprehension, plus supplemental subtests Information, Word Reasoning), *Perceptual Reasoning Index* (Block Design, Picture Concepts, Matrix Reasoning, plus supplemental Picture Completion), *Working Memory Index* (Digit Span, Letter–Number Sequencing, plus supplemental Arithmetic), and *Processing Speed Index* (Coding, Symbol Search, plus supplemental Cancellation).

While factor analysis is the most widely used multivariate analysis method, some non-metric alternatives have been developed to analyze relationships in psychological phenomena. Some of these alternatives relate to multidimensional scaling (MDS, Kruskal, 1964) and Smallest Space Analysis (SSA, a variant of MDS developed by Guttman, 1968). These methodologies represent variables as points in Euclidian space with interpoint distances corresponding to proximities measured among the variables (e.g. intercorrelations). The underlying rationale of this approach is that the isomorphism between the proximity measures among the variables and their interpoint distances in the Euclidian space enables direct observation of intercorrelation matrix. Another assumption of this approach is that geometric representation of order relations among variables, rather than mathematical expression of items' loadings on factors, may highlight in the data structures that are not so apparent in factor analytic solutions. The loss function for solutions based on this approach is Stress (Kruskal, 1964) or coefficient of alienation (Borg & Shye, 1995 p. 129; Guttman, 1968). These measures range from 1 to 0 (0 represents a perfect match).

For an intuitive explanation of MDS let us assume that we want to obtain a spatial representation of the intercorrelation matrix among *N* variables. In order to do that let us assume that we have *N* small metal balls — each representing a different variable. Furthermore, let us assume that all metal balls incorporate inside them magnetic forces that represent the intercorrelation among the variables. In this manner a very high correlation between two variables will be represented in a strong magnetic attraction between these balls while a negative correlation between two other variables will be represented by a repulsion between those balls. If we now put these balls on a square board, the overall configuration of the balls will depict the overall configuration of the intercorrelations among the *N* variables. Nevertheless, as a perfect match between the configuration of the intercorrelations and the configuration of the balls may not always be possible, the loss function will indicate to what degree the balls' configuration represents the intercorrelation matrix. Furthermore, while in the physical world only up to three-dimensional configuration among the balls is possible, mathematically any N-variable matrix may be perfectly represented in $N-2$ dimensions.

In view of the potential of MDS "in revealing insights that classical factor analytic techniques seem to have hidden (Sternberg, 1984; p. xii)," the scarcity of its application to the study of intelligence is surprising. Nevertheless, the few of these studies that exist yield interesting insights into the underlying structure of intelligence in general and I.Q. in particular. Indeed, the few studies that have focused on the study of intelligence by employing MDS approach indicated a radex model (L. Guttman, 1954). This model describes the simultaneous appearance of two orderings of the variables, one from the center to the periphery and the other a circular order around the center. This arrangement forms a disc in two dimensions or a sphere in three dimensions with sectors or conic areas relating to different characteristics of the variables. In ability testing this structure suggests the appearance of more cognitively complex tasks closer to the center of the figure and less complex tasks farther away from the center, with the appearance of verbal, numerical, and figural-spatial test content in separate sectors. The radex model of intelligence was tested through MDS (Marshalek, Lohman, & Snow, 1983; Snow, Kyllonen, & Marshalek, 1984) or SSA (Adler & Guttman, 1982; Beauducel, Brocke, & Liepmann, 2001; Koop, 1985; Guttman, 1965a,b; Peled, 1984; Schlesinger & Guttman 1969; Tziner & Rimmer, 1984, 1991; Ziedner & Feitelson, 1991). In all the above studies, encompassing various ability test batteries and various sample characteristics, the findings were more or less similar, indicating a two-dimensional solution where the tests were ordered from the most complex, abstract, inferential tasks near the origin, to the more simple tasks requiring associative learning at the periphery. Furthermore, in most studies, subtests that include items in the verbal mode (like vocabulary), figural-spatial mode (like matrices), and numerical mode (like mathematical