

CONTRIBUTION OF CATTELLIAN PSYCHOMETRICS TO THE ELUCIDATION OF HUMAN INTELLECTUAL STRUCTURE

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ABSTRACT

The development of a taxonomy of human intellectual structure has received much impetus during the last decade. Findings indicate that there are at least 30-40 primary abilities, rather than only the seven proposed by Thurstone. While this list does not constitute a definitive taxonomy of primary ability structures, nevertheless, much of the ability variance should be accounted for by the presently known factors. At the second stratum level, several major factors (Gf, Gc, Gm, Gps, Gr, Gv, Ga) have been well replicated in numerous studies. Evidence indicates a smaller number of primary ability factors in children and old-aged individuals. Several of the ability factors have been shown to significantly predict educational achievement at both elementary and secondary school levels.

Early work on human intellectual structure was carried out by Spearman and Thurstone (see Brody & Brody, 1976). Spearman advocated a general factor of intellectual reasoning (g) and a specific factor (s) on the basis of the limited statistical techniques available to him. Thurstone used the method of multiple factor analysis and concluded that there are at least seven primary ability factors which he labeled: Spatial, Perceptual, Numerical, Verbal Relations, Word Fluency, Memory, Induction. However, a second-order factoring of these primary factors resulted in higher-order factors at the level of Spearman's g factor (see Horn, 1986, p. 39). The two most prominent of such factors discerned by the Cattellian school were fluid (Gf) and crystallized (Gc) intelligence (cf. Cattell, 1980, 1982; Cattell, Schuberger, Ahern & Kameoka, 1981; Horn, 1978, 1979, 1980, 1982, 1986). Gf is the constitutionally and endowed (innate) intellectual potential which interacts with environmental experience (in accord with Piaget's cognitive developmental stage theory) to produce Gc which is the actual working intellectual level of a given individual. These factors, together with several of the primary ability factors, have been shown to relate significantly to educational achievement at both elementary and secondary school levels (Cattell & Butcher, 1968), as well as at college level (e.g., Boyle, 1983).

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In discussing the Gf-Gc theory, Schonfeld (1986, p. 204) pointed out that Gc is not merely the product of rote learning, but constitutes knowledge-producing (noegenetic) processes which are "nurtured by acculturation" (Horn & Cattell, 1966). Schonfeld further pointed out that Gc loads on tests of verbal comprehension, general reasoning and semantic relations, whereas Gf is independent of learning influences and loads on culture-fair tests such as Raven's Progressive Matrices, WAIS Block Design, and so forth. Schonfeld asserted that Gf is the more fundamental, biological adaptational ability. Additionally, Schonfeld (p. 205) argued that, "the Cattell-Horn view asserts that crystallized ability is truly knowledge producing . . . (which) becomes increasingly independent of fluid ability (Horn, 1978)."

While other investigators (notably Guilford) have attempted to develop a taxonomy of human intellectual abilities, these attempts have not been well received. Guilford's structure-of-intellect (S-O-I) model was severely criticized not only by Brody and Brody (1976, pp. 43-46), but even more discouragingly by Kline (1979, pp. 86-89). Furthermore, Horn and Knapp (1973) have also provided a severe critique of the Guilford S-O-I model. Kline (p. 89) concluded that, "the factor-analytic results purporting to confirm the Guilford model are based on a methodology that can confirm virtually any hypotheses . . . as a model of intellect . . . it cannot now be seriously considered." Carroll (1984a, p. 7) has reanalysed Guilford's data using more appropriate methods of factor analysis and has demonstrated empirically the inadequacy of Guilford's findings. As Carroll stated, "many of the Guilford et al. factors are artifacts of the methodology they used." In Cattellian terms, these are "bloated specifics." Indeed, Carroll's findings demonstrated, substantial agreement with structures . . . in studies by Cattell, Horn, Hakstian, and others (e.g., Hakstian & Cattell, 1978). In the light of this evidence, Guilford has been reanalyzing his data using oblique rotational strategies and has taken out higher-order factors (Guilford, 1981; Kelderman, Mellenbergh & Elshout, 1981).

Stankov (1983, p. 485) in discussing hierarchical theories of the structure of human abilities indicated that the Gf-Gc theory "is based upon factor-analytic evidence showing that there are broad organizations among the primary abilities that correlate (positively) among themselves and define a common factor at a higher order." In this regard, the Cattellian school has employed factor analytic methods in accord with Cattell (1973, pp. 282-287, 1978) and supported by Kline (1979) and Boyle (1985).

In reviewing the research on intellectual structure, Horn (1976) singled out the study by Hakstian and Cattell (1974) as the best and most methodologically sound evidence on the structure of human abilities (although it involved alternate forms of tests to define factors). Hakstian and Cattell measured 57 variables on 343 subjects. Nineteen primary factors were extracted and rotated to oblique simple structure. Because of the careful selection of variables, the heterogeneity of the sample, and precise factor analytic work, Kline (1979, p. 79) concluded that this study provided firm preliminary evidence on the structure of primary abilities. The resulting factors clearly supported those of Thurstone, but in addition included some new factors pertaining to memory, ideational fluency, and originality, for example (cf. Cattell, 1971). Subsequent research (e.g., Cattell,

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1982) indicates at least some 30 primary ability factors. Standard IQ tests such as the WAIS measure only a rather limited sample of the presently known primary dimensions (cf. Ekstrom, French & Harman, 1979; Horn, 1986, p. 49). Despite this limitation, the WAIS primaries still account for four higher-order ability factors relating to Gf, Gc, speediness and memory capacities.

At the second-stratum level, several major ability dimensions have emerged consistently from numerous studies (Cattell, 1982; Horn, 1986; Horn & Stankov, 1982). In addition to Gf and Gc, these factors have been labeled: Visualization Capacity (Gv), Auditory Organization (Ga), Perpetual Speed (Gps), Memory Capacity (Gm), and Retrieval Capacity (Gr). It is clear that abilities can be examined more parsimoniously in terms of this smaller number of secondaries, rather than in terms of the multitude of primary ability factors, but some predictive validity is sacrificed in the process. Woliver and Saeks (1986, p. 169) pointed out that Cattell's triadic theory of abilities "supposes that what we now throw together as secondaries are actually at two levels, which he calls general capacities — g's — (fluid and crystallized intelligence, speed, retrieval) and provencial powers — p's — which correspond to the main sensory integration areas of the brain: visualization, auditory ability, tactile and kinesthetic capacity, and so on."

Horn (1986, p. 44) commented that "the factor labeled Gf involves several forms of reasoning — apprehension of relations and eduction of correlates — that theorists such as Spearman (1927) and Jensen (1980) have said are the *sine qua non* of intelligence. But the factor labeled Gc also involves abilities that are said to be central to intelligence — breadth of information and reasoning with the concepts of the culture (Sternberg, 1985). Similarly, the Gv factor involves skill and visual thinking, such as is manifested in the genius of painting or sculpture or photography, and Ga indicates a broad set of capacities for dealing with the complexities of sounds, such as notable works of music." With regard to the speed factor, Horn (p. 48) commented that "some people are considerably faster in providing correct answers than are other people, but this is not very indicative of the level of difficulty with which they can successfully cope in intellectual tasks that measure Gf and Gc." Accordingly, performance on speeded (timed) intelligence tests is influenced markedly by an individual's speed ability irrespective of their Gf or Gc capacities. It is well known that personality characteristics (such as Introversiion/Extroversiion) greatly affect the speed factor. Hence IQ scores derived from speeded tests are often inaccurate for some individuals.

In regard to the developmental continuum, Undheim (1976) found evidence for only four of the second-stratum ability factors (namely Gf, Gc, Gv, and Gps). This does not however, preclude the possibility of finding a more complete complement of secondary ability structures in young (elementary school) children. Nevertheless, it does seem likely that memory and retrieval capacities may not be highly developed in preadolescent children. At the other end of the developmental spectrum, evidence has been forthcoming of some dedifferentiation of intellectual structure (Baltes, Cornelius, Spiro, Nesselroade & Willis, 1980). According to Baltes et al. (p. 634), "Specifically, there is a general collapse of the fluid/crystallized distinction with certain components of memory and speed tests joining in the formation of a general factor . . . Thus, a highly differentiated

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structure hypothesized on the basis of research with younger adults . . . does not provide a very useful structural pattern of psychometric intelligence in old age." Baltes et al. argued that a four-factor model is characteristic of intellectual structure in old age, Cunningham (1981, p. 19) argued that a decline in physical health and concomitant intellectual speed bring about a greater interdependence of the various intellectual abilities. Furthermore, Stankov (1983, p. 476) agreed with the assessment of Cunningham that the apparent decline in Gf with old age is merely an artifact resulting from reduced speed ability. In consequence, it appears that speeded IQ tests discriminate against older individuals.

Kline and Cooper (1984) factor analyzed the Comprehensive Ability Battery (CAB — Hakstian & Cattell, 1975) and reported strong support for Cattell's structural model of broad abilities. This model has been supported also by cross-cultural research (e.g., Hakstian & Vandenburg, 1979). As Carroll (1984a, pp. 2-3) pointed out, "The work of Cattell, Horn and Ralph Hakstian . . . with its specification of a small number of broad factors of intelligence, including 'fluid' and 'crystallized' factors, seems . . . the most promising model currently available." (cf. Carroll, 1984b, p. 306). While componential analysis (e.g., Sternberg, 1984) has been offered as supplanting the study of individual differences by factor analysis, this prospect has not been fulfilled (cf. Carroll, 1984a, p. 2). More realistically, Horn and Stankov (1982) have proposed a hierarchical model of intelligence, wherein the factor analytic findings have been cast into a cognitive information-processing framework. Their model takes into account not only primary and higher-order ability factors, but also comprises auditory and visual sensory-detector functions, as well as two broad memory components (SAR and TSR) — (see Stankov, 1983, p. 486).

In conclusion, it is evident that Cattellian psychometric research has produced a hierarchical structural model of intellectual abilities, comprising a number of general intellectual factors, together with several primaries and beyond that, the possibility of numerous specific abilities. This model has received considerable support from empirical research and more recently has been shown to be compatible with information-processing models (cf. Kline 1979, pp. 95-103; Gustafsson, 1984; Undeim & Gustafsson, 1987). The hierarchical factoring procedure enables the application of Cattell's *depth psychometry* approach, wherein the relationship of the primary ability factors to the higher-order factors can be elucidated. Simply retaining the first couple of general factors from a factor analysis of abilities would result only in pseudo-higher-order factors, with no information provided about the interaction of the primary abilities in producing the secondary and tertiary ability factors.

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