MODELS AND PARADIGMS IN PERSONALITY AND INTELLIGENCE RESEARCH

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by

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Central Position of Personality and Intelligence Research in Psychology

Psychology is distinguished from its brethren sciences of biology and sociology in that its main concern is with behavioral and mental processes of the individual (Zimbardo, 1992). Traditional study of personality and intelligence has focused on individual differences--searching for traits or relatively stable characteristics along which people differ (Eysenck & Eysenck, 1985; Howard, 1993). This line of research is based on the assumption that an improved scientific understanding of the nature of psychological functions can be achieved only by taking into account information about overall levels of performance and between-subjects variability and covariability. While the emphasis in individual differences research has been on multivariate procedures, experimental psychology has been almost exclusive in its focus on univariate designs. Multivariate research is closely linked to the development of psychological measuring instruments which are widely used in educational, industrial, and clinical settings. More recently, psychobiological explanations of personality and ability constructs have been sought (e.g., Zuckerman, 1991), opening the way for more sophisticated understanding of the neuropsychological and neuroendocrinological mechanisms underlying personality and ability traits. Hence, it is possible to claim that studies of intelligence and personality based on these combined approaches have made a more significant contribution to our social life in general than many other areas of psychological research (cf. Goff & Ackerman, 1992).

Cognitive tests are good predictors of many real-life criteria (Cattell, 1982, 1987a; Cronbach, 1990; Hunter & Schmidt, 1981; Jensen, 1980). Recent work, for example, has shown the validity of intelligence tests as predictors of death rates among males during the prime years (ages 20 to 40) of their adult lives (O'Toole & Stankov, 1992). Personality instruments, on the other hand, have been viewed as less adequate predictors of real-life criteria. Kline (1979) argued that correlations with personality traits (measured via instruments such as the 16PF, CPI, MMPI, MBTI, HPI, EPQ, PAI, etc.) seldom exceed about .30, accounting therefore for only a small proportion of the predictive variance. However, despite this widely held view that personality measures add only slightly to the prediction already achieved from cognitive ability measures, Boyle (1983) has demonstrated that under conditions of emotional arousal, the proportion of predictive variance accounted for by personality traits increases markedly. In Boyle's study, an experimental group of college students viewed a five-minute documentary film showing automobile accident victims. Intelligence, the most significant predictor of performance in the nontreatment group, was surpassed by personality/motivation variables, in contributing to prediction. The emotionally disturbing intervention produced a 36% increase in predictive variance, highlighting the role of non-ability intrapersonal variables, under conditions of emotional activation. Consequently, it appears that both intelligence and personality variables are very significant predictors of real-life performances (cf. Eysenck, 1990; Zuckerman, 1991).

Need to Study Personality and Intelligence from Diverse Viewpoints

Personality and intelligence are studied from several different perspectives today. Approaches range from those with a biological basis, to those that emphasize sociocultural influences. The central position is occupied by the traditional multivariate (Boyle, 1991) and experimental cognitive approaches (Stankov, 1989). Toward the biological end of the spectrum (cf. Zuckerman, 1991), there is a large body of research on the role of mental speed in intelligence (e.g., Jensen, 1980). Toward the anthropological and sociological end, studies have emerged in reaction to aspects of social policies, fashions, and other influences within our society. In regard to personality assessment, ratings (L-data), self-report questionnaires (Q-data), and objective tests (T-data) have all been utilized. For example, in the Q-data medium, significant intercorrelations between 16PF personality factors and cognitive abilities have been reported (Boyle, in press). A frequent finding is that scores on Intelligence (Factor B) are associated directly with scores on Dominance (Factor E). Moreover, exuberant/surgent individuals (Factor F) seem better able to express their intelligence with cleverness and a "sparkling wit." In military recruits, verbal ability has been found to correlate -.25 with Warmth (Factor A), -.35 with Exuberance (Factor F), and -.35 with Sensitivity (Factor I). As also reported in Boyle (1990b), several 16PF factors correlate significantly with ability measures (e.g., Dominance/Factor E (.20), Superego/Factor G (.27 to .30), Imagination/Factor M (.20), Shrewdness/Factor N (.26), Guilt Proneness/Factor O (-.25), Radicalism/Factor Q1 (.28), Self-Sufficiency/Factor Q2 (.25), and Self-Sentiment/Factor Q3 (.39). Both Self-Sentiment and Superego are "master sentiments" which play a central integrative role in intellectual-cognitive operations (Kline, 1979).

However, only T-data personality measures (e.g., Objective-Analytic Battery--Cattell & Schuerger, 1978) avoid the problems of item transparency and motivational response distortion (cf. Boyle, 1985). Ability-personality interactions are shown most clearly using such measures (Schmidt, 1988). Performance tests (as opposed to questionnaires or ratings) place greater demands on cognitive functioning. Schuerger (1986, p. 280) and Cattell (1987a, p. 452) reported several significant correlations between cognitive abilities and objective (T-data) personality measures (O-A factors labelled with a ***Universal Index*** or U.I. number) as follows: U.I. 16 Ego Standards (.21 to .48), U.I. 19 Independence (.46 to .60), U.I. 23 Mobilization vs. Regression (.48 to .59), U.I. 24 Anxiety/Neuroticism (-.24), U.I. 25 Realism vs. Psychoticism (.24 to .34), and U.I. 28 Self-Assurance (.38 to .45).

Dangers of Oversimplifying Personality and Intelligence Models

Some recent theories have taken the principle of parsimony too far. In the intelligence domain, researchers (e.g., Miller & Vernon, 1992) have endorsed not only the single (general) factor model but are also searching for the "basic process" that underlies intelligence. Jensen (1987), for example, attributes an important role to mental speed. In the personality area, Eysenck (1991) has argued for three rather than five or eight major dimensions. Several investigators (e.g., Deary & Mathews, 1993) have focused on the so-called "Big Five" personality dimensions, whereas Mershon and Gorsuch (1988) have shown that these dimensions measure but a fraction of the total personality trait sphere.

While we acknowledge the principle of parsimony and endorse it whenever applicable, the evidence points to relative complexity rather than simplicity. Insistence on parsimony at all costs can lead to bad science. Consider, for example, the assumption that frequency discrimination is the cause of individual differences on measures of intelligence. To test this assumption one might obtain scores on Raven's Progressive Matrices test (Raven, Court, & Raven, 1984), or Cattell's Culture Fair Intelligence Tests (Cattell & Cattell, 1977), and a measure of frequency discrimination--say the smallest difference between two tonal frequencies which a person can detect (Raz, Willerman, & Yama, 1987). A statistically significant correlation between these two measures provides supportive evidence for the assumption. If however, one remembers that Tonal Memory is one of several primary factors that define intelligence at some higher order of analysis, the study may lead to a different conclusion. Since it is likely that new Raz et al. measures will correlate mainly with Tonal Memory primary ability, not with intelligence test scores, the role of frequency discrimination in intelligence will appear less impressive. Within the hierarchical structure of abilities (Boyle, 1988a; Cattell, 1987a; Horn & Stankov, 1982; Stankov & Horn, 1980), the highest-order factor may exhibit negligible loadings on auditory frequency discrimination measures. Clearly, an overly simplified view of individual differences in personality and intelligence may attribute a greater than deserved role to a lower-order process because some of the nodes within the causal path have been omitted (see Schwartz & Reisberg, 1992, regarding parallel-distributed processing or PDP models).

Recent Research Models Within the Multivariate Psychometric Tradition

Multivariate Structure of Human Abilities

There have been only a few attempts during the past two decades to develop a comprehensive new theory about the multivariate structure of human abilities. For example, Jensen (1982) emphasized so-called Level I and Level II abilities. The main difference between these resides in the amount of transformation and mental manipulation required. This is minimal in tasks that measure Level I abilities (Digit Span tests are prototypical examples of such tasks). Level II abilities, however, require a large amount of mental manipulation. Marker tests of fluid intelligence (Gf--see Cattell, 1963, 1971) are good examples of the latter. The usefulness of this distinction was debated with some proponents of the theory of fluid and crystallized intelligence (Gf/Gc theory--Horn & Cattell, 1982; Horn & Stankov, 1982; Jensen, 1982; Stankov, 1987a; Stankov, Horn, & Roy, 1980), described below. A central issue was whether the Level I/Level II distinction could account for the richness and complexity of the cognitive domain. This debate strengthened the argument that short-term acquisition and retrieval function (SAR) is distinct from Gf. More recently, Jensen (Kranzler & Jensen, 1991) has abandoned his original interpretation of Level I/Level II theory. He now contends that a general factor loads on both Levels, but that Level I abilities exhibit smaller loadings than Level II abilities. Nevertheless, a large body of data suggests broad ability factors additional to the general factor, and at least some of the controversies surrounding Jensen's work can be attributed to the inherent simplicity of his model (see Stankov, 1987a).

Carroll (1976) classified primary mental abilities in terms of the then prevailing views about the architecture of the mind existing within experimental cognitive psychology. Reminiscent of Guilford's theory about the structure of abilities, it was called the "New Structure of Intellect" model--the three dimensions of Guilford's (1985) S-O-I model (contents, operations, products) corresponding to input, central processing, and output in information processing theories of cognition. Carroll's model assumed several memory stores (sensory buffers, short-term, intermediate, long-term memories) and provided a list of operations studied by cognitive psychologists, salient in measures of intelligence. He showed that each primary ability from the French, Ekstrom, and Price (1963) list involves a unique combination of memory stores and operations. Since this model provides a taxonomic starting point, Stankov (1980) used it as an input to a clustering procedure. The resulting tree diagram indicated several clusters of abilities that correspond to the broad factors of Gf/Gc theory. The fact that subjective analysis of the processes involved in primary factors leads to the same groups of abilities as obtained through hierarchical factor analysis was interpreted as support for Gf/Gc theory.

Carroll's work alerted researchers to the richness and relevance of cognitive theories (see Carroll, 1993). Both Jensen's Level I/Level II theory and Carroll's New Structure of Intellect model have strengthened the position of Gf/Gc theory. Messick (1992) compared factor analytic theories of abilities with two widely popularized theories of intelligence proposed by Gardner (1983), and Sternberg (1985). His conclusions favored the multivariate theories of intelligence--in particular, Gf/Gc theory. Indeed, Gf/Gc theory has become the most widely accepted psychometric paradigm of intelligence in existence today.

Multivariate Structure of Human Personality

In the personality area, only the 16PF has been based on a *comprehensive* sampling of the trait domain, as expressed in the lexicon (Boyle, 1990a). Krug and Johns (1986) have factor analyzed the 16PF scale intercorrelations on a massive sample of well over 17,000 individuals. They reported six second-stratum dimensions (Extraversion, Neuroticism, Independence, Tough Poise, Control, and Intelligence). This finding was then crossvalidated separately for the subsamples of 9,222 males and 8,159 females. In comparison, the work of McCrae and Costa (1987), was derived from a restricted sampling of the normal trait domain--a subset of only 20 of Cattell's original 36 trait clusters served as the starting point for the Norman "Big Five" which have ultimately been incorporated into Costa and McCrae's (1985) NEO-PI, and Goldberg's (1992) 50-Bipolar Self-Rating Scales or 50-BSRS. Thus, the currently popular Big Five cover only 20/36 (56%) of the normal trait sphere as measured in 16PF second-order factors (cf. Boyle, 1989a). Nevertheless, Mershon and Gorsuch (1988) have shown that the amount of variance account for by 16 factors far exceeds that accounted for by only five dimensions (see also the chapter by Boyle, Stankov, & Cattell). Zuckerman (1991) has pointed out that there are distinct advantages in examining an individual's profile of scores on a multitrait personality inventory, as opposed to just considering a few higher-order scores, which clearly provide less accurate prediction.

Role of Personality in Fluid and Crystallized Intelligence (Gf/Gc Theory)

Both Cattell (1987a), and Horn (1986, 1988) have reviewed recent literature on the Gf/Gc theory. The broad factors involve different cognitive processes which exhibit differential predictive validities, different genetic influences, and are susceptible to different sets of personality-learning influences (cf. Goff & Ackerman, 1992; Snow, 1989). Factor analyses of a representative sample of cognitive tasks known to be good measures of primary abilities, have revealed several broad factors (cf. Boyle, 1988a). These are: 1. Fluid intelligence, Gf; 2. Crystallized intelligence, Gc; 3. Short-term acquisition and retrieval function, SAR; 4. Tertiary (long-term) storage and retrieval, TSR; 5. Broad visualization, Gv; 6. Broad auditory function, Ga; and 7. Broad speediness function, Gs.

Both Gf and Gc are characterized by processes of perceiving relationships, reasoning, abstracting, concept formation and problem solving. They can be measured by speed and power tests, based on pictorial-spatial, verbal-symbolic, and verbal-semantic material. The main difference is that Gf (in contrast to Gc) depends relatively little on the effects of personality, formal education and acculturation. Elements of the problems, or operations performed on these elements are transmitted to the individual through formal societal means. Separate scores on Gf and Gc indicate an individual's potential for learning as well as amount of learning accumulated. This is more informative for many practical purposes than a single general ability score. Results (e.g., Goff & Ackerman, 1992) reveal that personality measures of typical intellectual engagement (as opposed to measures of maximum intellectual engagement and associated performance) correlate significantly with both Gf and Gc. Goff and Ackerman predicted that personality-intelligence correlations would be greater in relation to Gc than to Gf. They found that measures of typical intellectual engagement, extraverted intellectual engagement, absorption (in task), interest in arts and humanities, openness (to new experiences), hard work, and interest in technology, all exhibited significantly higher correlations with Gc than with Gf, as predicted. Accoring to Goff and Ackerman (p. 539), "Personality constructs that are related to intelligence might be best conceived of as constructs related to typical intelligence rather than as constructs related to maximal intelligence." Thus, the traditional approach of attempting to relate measures of typical personality to measures of maximal intellectual performance may involve a mismatch of personality and intelligence constructs, artifactually reducing the apparent extent of interrelation.

While Gf depends on the size and efficiency of working memory, Gc depends on size of the long-term store, on organization of information within that store, and efficiency in retrieving information needed for problem solution (Myors, Stankov, & Oliphant, 1989). Evidence of broad abilities additional to Gf and Gc suggests that performance on cognitive tasks depends not only on higher mental processes but also on lower-level cognitive processes. These include visual and auditory perceptual processes (Gv and Ga). These abilities capture parts of Gf and Gc that are perceptual in nature, and are sufficiently different and independent from Gf and Gc. The finding of separate factors suggests that some individuals are more efficient in processing auditory information, others visual information, and so on. Memory abilities (SAR and TSR) reflect storage areas useful for the operation of Gf and Gc, and indicate the relative independence of memory from the higher mental processes of Gf and Gc. Finally, broad speediness (Gs) reflects individual differences in speed of mental operations--individuals vary in their speed of cognitive functioning.

Gf/Gc theory shares common features with other major theories of intelligence including those of Thurstone, Burt, and Vernon (see Brody, 1992), as well as with the measurement of intelligence via standard tests such as the Wechsler scales (WAIS-R, WISC-R, WPPSI), or Stanford-Binet (SB-IV) revised by Thorndike, Hagen, and Sattler (1986)--(cf. Boyle, 1989b, 1990c). Gf/Gc theory is both more comprehensive and better supported by empirical evidence than alternative models and paradigms (Boyle, 1990b). The Gf/Gc distinction has provided an impetus for much of the life-span developmental research (see Horn, 1988; Stankov, 1986, 1988). These two broad abilities show distinct age-related changes. Performance on measures of Gc remain relatively stable or even increase during adulthood, whereas Gf measures show a decline starting around 30 years of age. This decline varies from study to study ranging from three to seven IQ points per decade of age with the median estimate between four and five IQ points for cross-sectional studies, and somewhat less for longitudinal studies (Brody, 1992). From among the remaining broad abilities, the long-term storage and retrieval function (TSR) behaves like Gc. All other broad factors (SAR, Gv, Ga, and Gs) decline in a fashion similar to Gf.

Cattell's (1987a) Triadic theory of intelligence is an attempt to organize human abilities not only in terms of structure and development but also in terms of their action. Cattell (1971) proposed that cognitive abilities can be divided into three main categories. First, *General Capacities*--Gf, Gs, TSR--represent limits to psychophysiological and neuroendocrinological brain action as a whole (Gf may represent the neural substrate)--(cf. Zuckerman, 1991). Second, *Provincial Powers* or capacities correspond to each of the various sensory modalities (e.g., Gv, Ga). Third, *Agencies* represent abilities which function in different areas of cultural content. Agencies correspond to Gc and primary abilities. According to Triadic theory, these three kinds of cognitive abilities combine in jointly influencing any actually observed behavior. Cattell's Triadic model of intelligence is superior to Sternberg's Triarchic model, in terms of its validity and more comprehensive scope of application (Brody, 1992).

Meta-Analysis of Psychometric Data Gathered this Century

Carroll (1993) reanalysed several hundred data sets from the most important psychometric studies of intelligence this century. The general conclusion from all these studies is in line with

Gf/Gc theory--the seven broad factors have been supported by Carroll's analyses. He does however, list a new broad factor--Processing Speed which appears in simple reaction time (RT) tasks and is distinct from broad cognitive speediness (Gs). Measures of mental speed obtained with the Hick's and inspection time paradigms (see below) load on this factor. Emergence of this new factor is a reflection of the increased interest in the role of mental speed in intelligence spurred by developments in computer technology during the past decade. Further work will probably provide additional broad factors. It is likely that broad abilities corresponding to other sensory modalities (e.g., touch, smell, taste) will be discerned. Horn (1988) claims there is already sufficient evidence that a broad quantitative ability (Gq) should be included in the list of second-stratum factors.

Re-Emergence of Guttman's Radex Model

Guttman's theory about the structure of human abilities has unfolded over the past 40 years. Rudiments of the theory appeared in his methodological papers on radex (radial expansion of complexity) in 1950s but the first "mapping sentence" that defines the main facets of his theory of intelligence appeared a decade later (Guttman, 1965). His latest version of the model has arisen from attempts to interpret the results of multidimensional scaling of data collected with the WISC-R (Guttman, 1992).

Guttman's radex model has three facets (see the description of facet theory in the chapter by Most & Zeidner, this volume). The Rule Task facet refers to the kind of task to be performed. It has two major elements: *inference*, where the subject infers a rule from examples or hints (e.g., a test of analogical reasoning); and *application*, where a previously learned or explicitly presented rule is to be applied (e.g., Who is the President of Israel?). These two correspond to what was previously called analytical ability. Achievement is still retained with a changed name--*learning*. This refers to the rule-application items based on short-term memory. In terms of a tree trunk analogy, the three elements of this facet represent concentric circles like yearly growth with inference being the middle circle. The Format of Communication facet represents the medium of the test items (*verbal, numerical, and geometrical-pictorial*). This corresponds to slices of the tree trunk that are similar in shape to a slice from a pie. Last is the Mode of Expression facet representing the way subjects respond to test items. It has three elements--*oral, manual manipulation,* and *paper-and-pencil.* This corresponds to tree trunk slices--i.e., small cylinders.

It is easy to link the five elements from this model to the seven broad Gf/Gc factors. If Gf corresponds to inference, and Gc to application, then SAR corresponds to learning of the Rule Task facet. Also, if Gv corresponds to the geometrical-pictorial and Ga corresponds in part to verbal, then Horn's (1988) Gq factor corresponds to the numerical element of the Format of Communication facet. However, there are no apparent links between the broad factors of Gf/Gc theory and the Mode of Expression facet. This is probably due to the fact that Guttman's recent model derives from the WISC-R battery whereas most other theories of intelligence have used one element--the paper-and-pencil Mode of Expression. Nevertheless, Horn and Knapp (1974) have shown that Guildford's *Products* dimension which corresponds to the Mode of Expression facet has very poor empirical support--this facet is not needed.

Two broad abilities from Gf/Gc theory--TSR and Gs--are not present in Guttman□s model. The TSR--or broad Fluency ability--is likely to reside close to the periphery of the slice representing Verbal mode of communication. The place of Gs within the radex is unknown at present. Finally, some aspects of Ga (e.g., nonverbal auditory tests) suggest it may be necessary to include a fourth medium of test items, say *tonal-musical,* to the Format of Communication facet.

Hierarchical Factor and Radex Models: Importance of the Concept of Complexity

Snow, Kyllonen, and Marshalek (1984) point to substantial agreement between hierarchical and radex models. Snow's work model comprises two facets. One corresponds to Guttman's Mode of Communication (verbal, numerical, and figural content) which can be visualized as pie-slices within a circular arrangement of tests. The second is represented by concentric circles for the Task Rule facet, but rather than labeling each circle as Guttman did (i.e., inference, application, and achievement), Snow acknowledged the variety of processes that co-exist within each concentric circle. He was still able to point to the essential feature--increase in task complexity as one moves toward the central circle. Furthermore, Snow et al. reported a high correlation between the loadings of the highest-order factor on tests, and the distance between the test's position and the center of the circle--i.e., between a test's complexity and its variance on the general factor.

Figure 1 presents an idealized radex model synthesized from the Guttman and Snow accounts, showing their similarities and differences. The concentric circles in the top shaded section are labeled in accordance with Guttman's Rule Task facet. The unshaded half of the circle is labeled in terms of Snow's intepretation. Guttman's labelling of the circles is rather restrictive--a process within the inner circles may be more complex than one in the outer circle even though one may hesitate to use the label *inference* or *application* to describe it. Thus, Snow's account is preferable. The positions of the tests are in general agreement with both accounts. There is no difference between the two models with respect to slices of the pie--verbal, numerical, and figural. However, we depart slightly from Guttman and Snow, leaving the middle circle intact in accord with Gustafsson (1992)--i.e., within the centre of the circle it makes little sense to distinguish between different Formats of Communication. This is closely linked to the well-known factor-analytic result that the mode of test presentation is of secondary importance for tests loaded highly by the general factor.

Insert Figure 1 about here

Snow questioned the task characteristics that lead to changes in complexity. The answer was that simple tasks "require relatively few component processes and relatively little reassembly of processing from item to item...More complex tasks...not only require more components but also more flexible and adaptive assembly and reassembly of processing from item to item." (Snow, 1989, p. 37). Snow's answer was based mainly on analysis of the psychological processes of tasks that led to the center of the circle. Several other investigators have addressed the same question using experimental manipulations.

Even though evidence for the broad factors of Gf/Gc theory is convincing, some researchers argue for an overriding general factor (Spearman's **g**). Gustafsson (1992) points out that the highest-order factor appears rather similar to the Gf second-order factor which is located in the center of the radex representation of abilities. Work with the Wechsler scales suggests that Vocabulary plays the central role (Mattarazzo, 1972). Evidently, the center of the radex--or the apex of the hierarchy--can shift depending on the nature of the test battery. Using a single marker test of Gf for the measurement of intelligence can perhaps be justified under the assumption that a representative sampling from the cognitive domain has been accomplished. However, as Zuckerman (1991, p. 54) has rightly pointed out, "A single average score on a nomethetic trait test offers little predictability..." Clearly, what is needed is multidimensional measurement across a range of factor analytically verified trait dimensions (Boyle, 1991). In this respect, Cattell's (1987b) *Depth Psychometry* has much to offer. For example, *quantitative* differences on the second-order 16PF factors can be investigated *qualitatively* in terms of their specific factor loadings on the primary trait factors. Use of Cattellian instruments such as the 16PF or CAQ therefore provides greater flexibility with respect to interpretation of both the primary and secondary factor scales.

Another Old Issue: Mental Energy versus "Bonds"

Two contemporary investigators emphasize the role of **g** rather than broad factors but take the traditionally-opposing views of its nature. Jensen (1985) takes a neo-Spearmanian view arguing that **g** is a single theoretical entity that determines correlation between cognitive tests. Humphreys (1979) takes a neo-Thomsonian position and assumes that there are many different facets of a large number of potential measures of cognitive ability. Humphreys believes that it is possible to define an indefinitely large number of relatively homogenous tests that differ in only one facet. These tests should exhibit positive intercorrelations (Guilford's "positive manifold effect").

Although Willerman and Bailey (1987) argued in favor of a unitary mental energy view, their arguments remain unconvincing (Brody, 1992). There is no empirical test yet that can help decide what theory should be endorsed. Cognitive psychology, however, seems to favor neo-Thomsonian views since the work within this tradition has produced a large number of *elementary cognitive tasks* (ECTs) easily linked to Thomson's concept of *bonds*. Some of these tasks have been used in recent work on intelligence. Thus, Kranzler and Jensen (1991) employed a battery of 11 psychometric tests and five cognitive tasks. These latter tasks were scored for 37 different ECT measures. The study investigated whether psychometric **g** represents a unitary process or a number of independent processes. Because the general factor from the psychometric battery shared significant amounts of variance with four principal components obtained from the ECT measures, Kranzler and Jensen concluded that **g** is not a unitary process. Apparently, Jensen has shifted away from his former strict neo-Spearmanian position. However, Carroll (1991) questioned Kranzler and Jensen's methodology, reanalysing their data to show that it was premature to reject the unitary **g** conclusion.

Different broad ability factors of the Gf/Gc theory are likely to call upon different sets of ECTs. If **g** is as important as these broad factors, what is its nature? While an indefinite number of facets or bonds may exist which can account for emergence of a general factor, we have to admit that Kranzler and Jensen had only a relatively small sample of tasks and it is not clear that these ECTs have properties assumed by Thomson's bonds. We agree with Carroll that Kranzler and Jensen's methodology was inadequate to answer their question even though we can accept the interpretation of **g** in terms of an indefinite and large number of bonds.

Studies of Material and Biological Substrata of Personality and Intelligence

An increasingly popular paradigm explores relationships between various bodily measurements and tests of cognitive abilities. These measurements range from rather crude physical assessments of body size to sophisticated recordings of cellular metabolic changes that take place while the brain carries out mental operations. Neuropsychological investigators are still searching for a reliable network of correlations between physical, personality and cognitive domains in hope of discovering *causes* of individual differences in cognitive abilities and personality structure within the brain itself (cf. Boyle, 1986; Powell, 1979; Zuckerman, 1991). Even though it is premature to make strong causal inferences at present, some interesting new results have appeared in the literature (see Zuckerman).

Anatomical Correlates of Intelligence and Personality

Jensen and Sinha (1992) have reviewed the literature about the relationship between various physical measures and intelligence. A particularly large and reliable database exists for the correlation with stature--i.e., general body size, height, and weight. That correlation is around +.20, attributable both to assortative mating for stature and intelligence, and to shared nutritional and health factors within families.

Another anatomical measure studied extensively is brain size (Jensen & Sinha, 1992). Intelligence test scores correlate between +.10 and +.20 with external head measurements, +.25 to +.30 with intercranial volume, and about +.35 with the direct in vivo assessment based on magnetic resonance imaging techniques. Rushton (1991) compared average cranial capacities of Mongoloids (1460 cm^3) and Caucasoids (1446cm^3), and it has been reported (see Lynn, 1987) that Mongoloids tend to obtain somewhat higher (about three to five IQ points) scores on intelligence tests than Caucasoids. However, given the very small within-race correlation of brain size and intelligence, and very small (trivial) Mongoloid-Caucasoid differences in IQ and in brain capacity, it would be irresponsible to draw any strong conclusions. More recently, Rushton (1993) has revised his work on sex differences in brain size and intelligence. There are many problems with this line of research (e.g., all the above correlations are for brain measurements statistically corrected for overall body size). Willerman (1991) has questioned the appropriateness of this correction since body weight differences between the subject samples studied by Rushton account for most of the variance in cranial capacity. Also, Cain and Vanderwolf (1990) argued that racial differences in brain size have no necessary implications for intelligence, especially since there are no significant sex differences in overall intelligence levels, even though men on average have larger brains than women (cf. Ankney, 1992).

Biochemistry and Intelligence: Role of Serological, Mineral and Vitamin Imbalance

Jensen and Sinha (1992) observed that intelligence exibits a low negative correlation (less than -.20) with the age at which girls first menstruate. Therefore, hormonal factors are possibly involved in intelligence. They also reported that individuals whose blood contains a greater than normal amount of serum uric acid or SUA (i.e., in sufferers from gout) tend to be high achievers. This may be linked to the caffeine-like effects of SUA. Its correlation with intelligence *per se* is very low and trivial (less than .10), accounting for no more than 1% of the predictive variance! Since 99% of variance is not accounted for, it seems unlikely that SUA has any substantial impact on intellectual functioning.

There have been reports of successful attempts to increase intelligence using nutritional means. For example Schoenthaler, Amos, Eysenck, Peritz, and Yudkin (1991) studied 615 primary school children showing that supplementary vitamin intake over a period of four weeks can increase scores on Gf but not Gc. Using USA guidelines for recommended daily allowances of minerals and vitamins, this study tested the effects of several different intakes. The lowest dose was 50% of recommended daily allowance. Subjects within treatment groups exhibited a statistically significant, slight increase over placebo controls. On average, a maximum of only four IQ points was gained through intervention that assures a normal daily intake of vitamins and minerals.

Brain Glucose Metabolism in Personality and Intelligence

Diabetes melitus is associated with impairment of memory, retrieval efficiency, abstract reasoning, problem solving and increased difficulty in coping with complexity (Dunn, 1992). Performance on simple RT tasks and on forwards, but not backwards, digit span tests is similar between diabetic patients and normal controls. Diabetic patients perform worse than normal subjects on measures of Gf--i.e., on complex abstract reasoning tasks, but do not differ from normal controls on Gc. While Langan, Deary, Hepburn, and Frier (1991) reported a significant correlation between frequency of severe hypoglycemia and performance IQ, this relationship did not emerge with verbal fluency and auditory learning scores. Also, Deary (1992) demonstrated the critical role of frequent severe hypoglycemia in development of cognitive deficit. Concomitant subtle personality changes would also be expected (e.g., Zuckerman, 1991, has reported that disinhibition and increased levels of extraversion are associated with brain damage).

Aerobic glucose metabolism is the source for almost 95% of cerebral energy, with the synapse being the major location for consumption. The human body is protective of the brain's operation. If there is metabolic disturbance, all other organs are depleted of glucose prior to the brain showing any signs of a lack. Since glucose metabolism is important for brain functioning (Vernon, 1991), it is logical to expect disturbances in prolonged or severe diabetis melitus. Grill (1990) reported a significantly lower global cerebral blood flow in diabetic patients, and that the ratio of oxygen to glucose uptake is lower in diabetics. Moreover, a small but significant release of two byproducts of the nonoxidative metabolism of glucose--lactate and pyruvate--are present to a larger extent in diabetics. Fox, Raichle, Mintun, and Dance (1988) reported that the oxygen/glucose metabolic ratio fell markedly in healthy subjects in areas of the brain with acutely increased neural activity. The decrease was associated with increased in cerebral blood flow and with the regional uptake of glucose, but only a slight increase in oxygen uptake. Vitamin C plays an essential role in glucose metabolism. This may partly explain the slight improvement in intelligence test performance as a result of vitamin and mineral supplementation (Schoenthaler et al., 1991).

These findings suggest that the oxygen/glucose ratio may relate to the difficulty/complexity level of a cognitive task. Grill (1990) suggests that the increase in nonoxidative metabolism of glucose could reflect a state of brain overnutrition. Thus, the diabetic state as well as causing acute increases in neural activity may lead to an oversupply of nutrients to the brain. This is a clear example of inefficient functioning at a physical level which may be responsible for the reduced ability of diabetics to cope with complex problems. Indeed, it may be related to poor performance on intelligence tests even in non-diabetic individuals (Stankov & Dunn, 1993).

Neural Efficiency Hypothesis

Brain-imaging techniques such as positron emission tomography (PET) and cerebral blood flow or CBF (see Vernon, 1991), depend on use of nuclear isotopes--a byproduct of glucose metabolism is the tracer in PET research, and oxygen provides a tracer in CBF studies. For example, Metz, Yasillo, and Coopers (1987) carried out PET scanning as subjects performed a Wisconsin Card-Sorting Test, and also during a simple control task. Traditionally the frontal cortex has been assigned a special role in attention and in dealing with complex tasks, but Metz et al. (1987) reported a uniform global rather than localized metabolic increase in cortical activation almost 30% above the control level. Frontal lobe impairment diminishes associational, relation-perceiving powers in the emotional control and impulse deferment-inhibition processes (Cattell, 1987a). Consequently, this "frontal lobe" projection of intelligence into personality partly suggests how intelligence modifies personality (cf. Zuckerman, 1991).

Haier et al. (1988) did not find significant differences in absolute cerebral metabolic rate for glucose between three levels of task complexity. Several localized regions of the brain showed more activity when subjects worked through the complex Raven's Progressive Matrices test than when doing a visual search task (i.e., pressing a key whenever 'O' appeared on the computer screen, or simply attending to a changing series of digits without responding). Particularly affected were the occipital posterior areas of the brain. Haier at al. reported that simple visual search and other control tasks (i.e., tasks of low complexity) showed nonsignificant correlations with measures of metabolic activity. Raven's test, on the other hand, exhibited highly significant correlations with cerebral metabolic glucose rate, ranging from -.44 to -.84, depending on the locus of brain activity. This suggests that subjects with higher Raven's scores took up less glucose than those with low scores. Vernon (1990) reviewed the literature on speed of mental processing, EEG, and PET, concluding there is sufficient support for the Neural Efficiency Hypothesis (cf. Vernon & Mori, 1992). If higher intelligence is associated with less energy demanding, faster neural systems, this hypothesis suggests that intelligence is not a function of more brain activity, but rather efficiency of brain processes relevant to a particular task.

Health Issues in Relation to Intelligence, Personality and Aging

Severe and prolonged illness may affect personality and intellectual functioning. Yet, there is a scarcity of information about the impact of less severe illness. For example, we do not know much about the effects of the common flu that affects much of the population. We also know little about the prevalence of some conditions that influence personality and cognitive performance (e.g., chronic fatigue syndrome). These illnesses are part and parcel of everyday living.

There is a dearth of theories about the effects of health and physical well-being on personality and cognitive abilities. Birren and Cunningham's (1985) Cascade Hypothesis is one of the few attempts to operationalize "Chronological Age" in terms of Primary and Secondary Aging and to relate these to cognitive function. They propose that Primary Aging (innate maturational processes captured by sensorimotor tests) causes a decline in perceptual speed. Secondary Aging (disease) is causally related to a decline in perceptual speed and reasoning. The Terminal Drop (decline in intellectual functioning about five years prior to death) is causally related to diminished verbal comprehension, reasoning abilities, and perceptual speed. The assumption that decline in perceptual speed occurs prior to decline in fluid abilities is not supported by Kaufman (1990). When perceptual speed is controlled statistically, residual age-related differences remain in inductive reasoning and spatial orientation. The effects of poor physical health on personality and intellectual functioning remain somewhat equivocal. Thus, Perlmutter and Nyquist (1990) demonstrated a relationship between self-reported health and intellectual performance, whereas Salthouse, Kausler, and Saults (1990) found no such association (cf. Fernandez, 1986; Fernandez & Turk, 1989).

Anstey, Stankov, and Lord (1993) measured health, physical activity, education, and chronological age in 100 community dwelling women aged 65 through 90 years. They were also given a battery of cognitive tests of fluid intelligence, as well as a wide-ranging battery of sensorimotor tasks. As expected, health had a significant negative effect on sensorimotor variables--older people have more difficulty with sensory tasks and tasks requiring motor activity. Although sensorimotor processes affected Gf, the indirect effect of health on Gf was not significant. Nor was physical activity related to Gf. Again, chronological age did show a significant negative relationship to Gf. These data supported the findings of Salthouse et al. (1990)--higher mental functions seem to be largely spared the effects of transitory physical illness.

Among the many personality dimensions related to health, perhaps the most important is neuroticism, which is predictive of a variety of mental health indicators (Wistow, Wakefield, & Goldsmith, 1990). Neuroticism involves anxiety, stress, depression, regression, and guilt components (Boyle, 1989c). Deary and Mathews (1993) have reported that neuroticism is directly implicated in "dysthymic" neuroses including anxiety, stress and depression, drug addiction, certain types of criminality, sexual difficulties, poor body image, disease proneness, and poor cognitive performance (see also Davis, Elliott, Dionne, & Mitchell, 1991; Eysenck, 1976; Eysenck & Eysenck, 1985; Friedman & Booth-Kewley, 1987; Gossop & Eysenck, 1983; Mathews, Coyle, & Craig, 1990; Ormel & Wohlfarth, 1991; Stone & Costa, 1990; Suls & Wan, 1989; Watson & Pennebaker, 1989).

Varieties of Speed Measures and Individual Differences

Mental speed can be defined operationally in many different ways and aside from Carroll's (1993) work, Vernon and Weese (1993) have examined multiple speed of information-processing tasks as predictors of intelligence. Measures of speed can be divided into three main groups. First, most studies employ speed as a dependent measure. Since many theories in experimental cognitive psychology deal with processes that are too short to be captured by crude accuracy (i.e., number correct) scores, speed of doing a task (or parts of a task) is used as a sensitive measure of components of the thinking process. This approach allows for measurement of elementary cognitive operations or ECTs (see below). Other studies view speed as a property of an organism. Usually, a very simple task is chosen and subjects have to perform it as quickly as possible. The computer analogy is often used--the assumption being that the main cause of individual differences is the difference in "ticking of the internal clock." Most work deals with measures both of simple and choice RT, and inspection time (IT). The third group of studies focuses on speed in carrying out complex cognitive tasks.

Intepretation of results is not solely in terms of mental speed as an expression of some physical property of the organism, but also in terms of stylistic factors associated with working through cognitive tasks.

<u>Reaction Time Studies Related to Hick's Law</u>

The measurement of speed of cognitive processes in relation to personality using RT has aroused much interest among researchers (cf. Robinson & Zahn, 1988). New technology and theoretical developments within experimental cognitive psychology are the main reasons for this renewed interest. In what way has our knowledge improved because of this flurry of activity?

Simple and choice RT measured with the Roth-Jensen apparatus and Crossman's card-sorting task have provided the largest body of data. In both procedures, amount of information processed is systematically increased. The Roth-Jensen apparatus consists of a panel with a "home" button and eight small lights arranged in a semicircle around it. Next to each light is a "turn-off" button. The most commonly used number of visible lights is one, two, four and eight. The subject holds a finger on the home button, and when a light comes on, raises the finger (decision time) and quickly moves to extinguish the light (movement time). In the Crossman task, the subject sorts ordinary playing cards into varying numbers of piles--typically two, four and eight. In the two-pile version, the subject may have to sort all red cards into one pile and all black cards into another pile. In the four-pile version, piles may be defined with respect to suit, etc. Speed of sorting indicates both decision time and movement time. There is usually another two-pile version in which subjects sort cards consecutively into two piles without any concern about the nature of cards. This is interpreted as movement time.

Reaction Times measured with these procedures show a pattern described by Hick's Law--there is a linear relationship between decision time and the natural logarithm of the number of piles or visible lights in the display (i.e., number of "bits"--where 1-bit corresponds to two alternatives; 2-bits to four alternatives; and 3-bits to eight alternatives). As tasks become more complex, it takes longer to reach a decision. For each subject, median RT for each bit, intercept and slope RT measures is obtained. With the Roth-Jensen procedure, the variability score is also available, and in both tasks, separate movement time scores exist.

Since the first report of noteworthy correlations (Jensen, 1979), many studies based on the Roth-Jensen apparatus have been published. While speed plays a role in intelligence, a dispute exists about its relative importance. There are also theoretical problems. For example, different measures exhibit significant correlations with intelligence. Even in Jensen's original study, the highest correlation with intelligence was not for the slope measure but for the variability score. Individuals with lower intelligence tend to exhibit a greater difference between their highest and lowest speeds. RT scores from the five slowest trials suggest that individuals with low intelligence cannot maintain their performance at optimal level (Larson & Alderton, 1990). Since the slope measure reflects the time needed to process an additional bit of information (increase in complexity), the slope should exhibit a higher correlation with intelligence than with RT variability. In fact, choice RT measures do not correlate more highly with intelligence than do simple RT measures. In most studies, the intercept measure does not correlate highly with intelligence whereas movement time does (Jensen, 1987). Explanations of the discrepant results have acquired a very strong *ex-post-facto* quality and it is hard to see how further work could serve a useful purpose.

Correlations between intelligence and speed measures from the Roth-Jensen choice RT apparatus rarely exceed -.30 (Jensen, 1987). This correlation is not higher than that obtained with many other cognitive or psychobiological measures (Boyle, 1988b). Furthermore, as pointed out by Cattell (1987a), the correlation between the higher-order speed factor (Gs) and fluid intelligence (Gf) was .39 (accounting for only 16% of variance--i.e., 84% unexplained). Jensen's (1980) attempt to measure intelligence using RT cannot hope to exceed this value. Consequently, our substantive knowledge has improved little as a result of all this activity.

Performance on Crossman's task was also correlated with measures of intelligence. The emphasis has been on examining correlations between speed of card sorting and intelligence as the number of piles increases from two to eight. The feasibility of Hick's law has been examined at the group level but little emphasis has been placed on estimates of the individual's slope and intercepts. Analogous data have been reported for the Roth-Jensen procedure (see Jensen, 1987)--correlations between median RT and intelligence increase with the number of bits of information processed. Nevertheless, as shown in Table 1, the increase in size of correlations for the Roth-Jensen apparatus is not dramatic.

Insert Table 1 about here

Roberts, Beh, and Stankov (1988) used Crossman's card sorting task and reported a pronounced increase in correlations between the 0- and 2-bits levels, but a drop at the 3-bit level, attributed to processing capacity limitations (this drop in correlation at the 3- bit level was not replicated by Roberts, Beh, Spilsbury, & Stankov, 1991). Another feature of the Roberts et al. (1988) work was the requirement to sort cards not only under the typical "single" condition but also together with a word-classification task--i.e., under a "competing" condition. Table 1 shows that correlations of the competing condition exhibit the same pattern as the single condition across bit levels. Additionally, competing conditions also exhibit higher overall correlations with intelligence. This finding points to the importance of complexity in intelligence and to the possibility of using experimental manipulations in studies of task complexity.

Visual and Auditory Inspection Time

Another measure of speed that correlates with personality and intelligence is inspection time (IT). There are two versions of this paradigm: visual and auditory. In both versions, an aspect of exposure time is varied using some accepted psychophysical procedure, and the score is the minimum time needed to detect the difference between two simple stimuli. In the visual IT task, the stimuli consist of two simultaneously presented lines that differ in length (see Nettleback & Lally, 1976). The task is to state which line is longer. In the auditory task of Deary (1992), the stimuli to be discriminated are two square wave tones (870Hz and 770Hz) presented at 80 dB. Both tones last for equal time periods and there is no gap between tone pairs. However, the time interval for presentation of the pair varies so that tones are heard as increasingly shorter sounds. The aim is to establish the shortest time interval (i.e., tone duration) which the subject can (with 90% accuracy) state whether the order of tones within a pair is "High-Low" or "Low-High."

Kranzler and Jensen (1989) reported a correlation between IT and Gf measures of -.29, although other studies report higher values. There are problems with IT research (Levy, 1992). First, because IT measurement is time consuming, only a small number of subjects has been employed in many studies. Higher correlations with intelligence are obtained when extreme groups (mentally retarded vs. university students) are used. Second, there are problems with the psychophysical methods used and with experimental procedures. Consequently, up to 40% of subjects do not produce valid data that can be correlated with personality or intelligence. Third, there are serious problems with theoretical accounts of IT measures and their correlation with personality and intelligence (Mackintosh, 1986). The latest interpretation is that higher IT threshold is associated with lapses of attention characteristic of individuals with lower intelligence. At this stage, there is no firm evidence to support this hypothesis.

Primary Abilities of Mental Speed

At least two factors capture different aspects of mental speed. They are usually considered to be more complex than RT and IT measurements (cf. Buckhalt & Jensen, 1989).

Natural Tempo

It is assumed that individuals have a natural speed of thinking. One way to measure speed is to give a task with the instruction to work at the "most comfortable pace." An approximation to this approach is provided by the Tempo test in which a subject is induced to count a particular beat and, after a period of time, the count is compared with that of a metronome. Some individuals overestimate the beat of the metronome, others underestimate it--the amount of discrepancy may provide information about the Natural Tempo. Traditionally scored tests of Tempo measure ability to Maintain and Judge Rhythm (MaJR) at the first order of analysis, and Ga at the second order. Stankov (1986) reported a pronounced effect of aging on MaJR, amounting to a loss of about five IQ points per decade of age. It is possible that a changed scoring procedure will show correlations with RT and IT tasks and define a different factor.

Perceptual-Clerical Speed

Tests of Perceptual-Clerical speed have gained in importance in part because of an increased emphasis on speed in studies of aging (Cornelius, Willis, Nesselroade, & Baltes, 1983), and to a realization that these tests measure selective attention processes. Recent interpretations of attention, are in turn, akin to Spearman's mental energy and, as mentioned earlier, to Thomson's bonds (Stankov, 1983, 1988). One interesting finding has been that impulsive individuals tend to be fast but inaccurate in visual pattern matching tasks (Dickman & Meyer, 1988), implicating the important role of personality dispositions in relation to speed and accuracy. Future research into Perceptual-Clerical speed tasks will need to examine their relationships with other types of speed measures. Recent findings (e.g., Robinson & Zahn, 1988) suggest that RT and IT measures exhibit significant correlations with this factor.

Test-Taking Speed, Personality and Intelligence

Computerized test administration provides an easy way to measure the time needed to answer each item, as well as detailed information about the speed of test-taking. Speed scores from batteries of diverse personality and intelligence tests tend to exhibit somewhat higher average intercorrelations than accuracy scores, supportive of a broad speediness function (Gs). Second, if we correlate accuracy scores from a test of Gf with speed of test-taking scores from a variety of cognitive tests, the size of correlations will depend on the nature of the tests. In general, speed in doing easy tasks shows higher correlation (in the .30s) with intelligence, whereas speed in doing difficult (power) tests shows zero correlation (Spilsbury, Stankov, & Roberts, 1990). Personality factors such as Extraversion-

Introversion may play an important role, in that the more introverted individual may work more slowly, but also more carefully and thoroughly, double-checking all answers, and so on. Speed scores may represent different things depending on the perceived difficulty of the task. At an easy level, they may be measuring aspects of Gf, but other non-ability intrapersonal factors--maybe stylistic or perhaps related to self-esteem, confidence or introversion may come into play when the task becomes difficult. Thus, Boyle (1983) demonstrated that under non-emotive conditions, intelligence accounted for most variance in academic learning whereas under stressful conditions, personality factors accounted for most of the predictive variance (as discussed above).

Composite Scores

A composite of speed and accuracy divides the number of correctly answered items with the time needed to take the test. Spilsbury et al. (1990) employed such an "efficiency" score with a deductive reasoning test. The efficiency score had several properties (e.g., a significantly higher correlation with Gf) making it superior to both accuracy and speed scores alone. However, this result was not replicated with an inductive reasoning test used by Stankov and Cregan (1993). Perhaps the usefulness of the efficiency score may vary across different tasks and/or samples.

Individuals performing cognitive tasks operate at different levels, depending on their understanding of the instructions and general requirements of the task. Some work quickly and sacrifice accuracy, and *vice versa*. According to Lohman (1989), this trade-off can be substantial. This was of particular concern to experimental cognitive psychologists who adopted the practice of using only data from subjects who showed a very high accuracy level, say 90-95% correct. At that level, the trade-off is small and measures of speed are sensitive to task manipulations only. Lohman has argued that individual differences in speed-accuracy trade-off can affect performance on intelligence tests. One way to reduce this problem is through explicit instructions which emphasize either speed or accuracy. Stankov and Crawford (1993) studied the effects of variations in instructions on a test□s correlation with external measures of Gf. The same task was given twice, so that both accuracy and speed scores were available. Results showed there were no significant changes in correlation between this task and Gf due to differences in instructions. Thus, the effects of speed-accuracy trade-off may be relatively unimportant.

Contributions from Experimental Cognitive Psychology

Hunt (1980) listed three areas of research in contemporary cognitive psychology that contribute to our understanding of intelligence. These are ECTs, cognitive strategies, and limited-capacity constructs (e.g., working memory and attentional resources). Every task, even the simplest one, is assumed to have an associated set of cognitive strategies--often unique to the task--that can be employed for its solution. It is assumed that more intelligent individuals have a greater variety of strategies at their disposal, and that they can choose the most appropriate one for the task in question. Strategies are sometimes hard to distinguish from ECTs (Ferretti & Butterfield, 1992). The term "strategy" may be employed in the sense of "cognitive style." In other cases, an "executive" or homunculus that makes a choice from among the available ways of solving a problem is postulated. The most successful use of the construct of strategy has been in the attempt to teach borderline or mentally retarded individuals how to improve their performances on intelligence tests (Ferretti & Butterfield). In other areas however, ECTs and limited capacity constructs seem to provide a sufficient explanation of individual differences.

Traditional Information-Processing Framework: Elementary Cognitive Tasks

Several hundred ECTs have been investigated. They can be used as in Thomson's "bonds" to provide an account of the general factor. Since the traditional information-processing framework assumes various stages of processing (i.e., sensory buffer, central processor, and output system), the nature of these ECTs vary. ECTs associated with peripheral functions are likely to differ in relation to intelligence and personality, as compared with ECTs from the center. Hunt (1980) listed ECTs associated with retrieval of information from the long-term store using a "name- vs. physical-identity" task, a short-term memory search task, and processes associated with verbal abilities. Sternberg (1985) constructed ECTs derived from the analogical reasoning task, involving preparation encoding, inference, mapping, application, justification, and response. Salthouse (1985) listed 45 ECTs studied in relation to aging. Hunt was not impressed with the size of correlations of ECTs with measures of intelligence (maximum around .30). He therefore turned his attention toward attentional resources which seemed to hold promise of producing higher correlations.

Role of Capacity in Individual Differences

Individuals differ in their cognitive capacity. Two theoretical constructs--working memory and attentional resources--have both been linked to intelligence.

Working Memory

Since working memory has two parts--passive or storage and active or manipulative--digit span tests, visual sequential memory tests (e.g., as in the WAIS and ITPA tests respectively), and other measures of short-term memory are viewed as an inadequate means of capturing its full meaning.

Although working memory seems particularly involved in Gf, there have been attempts to study it in relation to Gc. For example, Daneman (1982) assumed that working memory was important for successful reading comprehension. Her test of working memory consisted of a series of long sentences and subjects had to recall the last few words from these sentences. She expected poor readers would devote so much capacity to producing sentences that they would have less residual capacity for storing and producing the final words. Her results supported this hypothesis. At present we do not know the extent of her test's correlation with a variety of intelligence and personality measures.

Working memory is of major importance in two primary Gf abilities. Several types of tests define the *Temporal Tracking* primary factor (Stankov & Horn, 1980), but mental counting tests seem to capture its essence best. The task is to count the number of times a particular stimulus is presented. Stimuli can be names, words, pictures, sounds or combination of all these. Typically, three or four different categories of stimuli are employed. Mental counting requires keeping in mind the tally for every stimulus (storage) and updating the counter (manipulation of new and stored stimuli).

Working memory is also present in the *Inductive Reasoning* primary ability of Gf (e.g., the series completion tests developed by Thurstone--see French et al., 1963). Computer models of both Letter and Number Series tests can produce the series employed in Thurstone's tests by manipulating a number of parameters. Holzman, Glaser, and Pellegrino (1983) demonstrated that the most critical aspect is the parameter known as number of working memory placekeepers (or WMPs). To illustrate what is meant by WMPs, consider the following examples of Letter Series items:

One-operator rule: [X_1,X_1,**+N(X_1)**] Example: P,P,R,R,T,T,V (Ans: V)

Two-operators rule: [X_1,**+N(X_1)**,X_2, **+N(X_1)**] Example: V,L,X,N,Z,P,B (Ans:R)

The rules consist of variables (denoted X) and operators (denoted **+N(X)**), enclosed between square brackets which correspond to cycle length of the item. The values of variables, once initialized, change from one cycle to the next according to the operator. It is easy to generate analogous series by choosing different values for X□s. Number of WMPs can be increased at will by the experimenter. The difficulty of series completion items depends almost entirely on the number of operators used, or number of WMPs. It does not depend on other parameters derived from the rule--number of variables, length of series, and so on. Also, the test's correlation with other measures of Gf depends more on number of WMPs than on any other parameters (Myors et al., 1989; see Table 3 below). Individuals who obtain higher intelligence test scores can keep track of a greater number of things that can change in the series completion problems. In addition, there is evidence that personality affects working memory performance (Eysenck, 1983), suggesting a likely interaction between cognitive and personality factors.

Attentional Resources

The construct of attentional (or processing) resources is also linked to capacity. It differs from working memory in that it is not restricted to central processes within immediate awareness. Processes involved in long-term memories and central processes that closely interact with peripheral sensory activities, are also part of the conglomerate. The construct of attentional resources resembles Spearman's ideas about mental energy.

Measurement operations developed for assessment of available resources involve the use of dual tasks. Every task requires certain resources for its execution. Two versions of the dual tasks have been employed: (a) Primary-secondary task paradigm (Halford, 1989; Hunt & Lansman, 1982); and (b) Competing task paradigm (Fogarty & Stankov, 1982, 1988). Since two concurrent tasks require more attentional resources than a single task, decrement in performance in dual tasks is an indication of demand for resources. Since individuals differ in available resources, dual tasks should exhaust individuals' resources more quickly, with resultant changes in correlation of the task with measures of intelligence. Eysenck (1979) has shown that depletion of attentional and cognitive resources can be severe under anxiety inducing conditions (during processing of cognitive tasks). Anxious individuals can be highly sensitive in dual task situations and suffer larger decrements in cognitive performance than less anxious persons.

In the primary-secondary task paradigm, subjects respond to an intelligence test with items of increasing difficulty (primary task). Simultaneously, they perform a simpler secondary task--say, pressing a button upon hearing a tone. The expectation is that individuals with lower intelligence, and fewer attentional resources will show signs of disruption in secondary task performance while working at relatively easy levels of an intelligence test. However, many assumptions have to be satisfied before one can test this theory (Stankov, 1987b).

Role of Complexity in Individual Differences

Recent studies of complexity in relation to intelligence have used competing tasks and single tasks with carefully graded levels of increasing complexity.

Competing Tasks

The competing task paradigm differs from the primary-secondary task paradigm in that both components are subtests from intelligence test batteries, they are of about equal difficulty, and receive equal emphasis. These tests are given as single tests and again simultaneously--as in dichotic listening experiments, or one through earphones and the other on a computer screen. If performance declines under the dual condition, tests are competing for attentional resources. If they also show higher correlation with IQ measures under competing conditions, attentional resources theory can provide an account of individual differences. Studies have investigated about 50 different competing tasks involving marker tests for primary abilities of Gf, Gc, SAR, Ga, and Gv (see Fogarty & Stankov, 1982, 1988; Myors et al., 1989; Roberts et al., 1988, 1991; Spilsburry, 1992; Stankov, 1983a,b, 1986, 1988, 1989; Stankov, Fogarty, & Watt, 1988; Stankov & Myors, 1990; Sullivan & Stankov, 1990). Overall, evidence indicates that (a) Intercorrelations within a battery of competing tasks tend to be higher than intercorrelations of the same tests given singly; (b) Competing tasks tend to have higher correlations with external measures of intelligence than do the same tests given singly; (c) Changes in the magnitude of correlation coefficients do not necessarily parallel changes in arithmetic means--correlations can increase even though single and competing tasks may be of equal difficulty; (d) Extraverted individuals perform better, exhibiting greater selective recognition of attended to information in dichotic listening tasks (Dunne & Hartley, 1985).

Processes involved in competing tasks include dividing attention, ability to resist interference, and higher-order planning. Attentional resources theory is threatened by point (c) above. If performance initially is below ceiling levels and there is no further reduction, competing tasks do not demand more attentional resources than single tests and therefore attentional resources theory cannot account for the increase in correlation. Multiple resources theory (Wickens, 1980) may explain the findings with mean scores but cannot provide a parsimonious explanation of the general increase in correlations between cognitive tasks.

<u>Single Tasks</u>

Ceci (1990), Guttman (1992), Larson, Merritt, and Williams (1988), Snow (1989), Spilsbury (1992) and many others highlight the importance of complexity in personality and intelligence research (e.g., Eysenck & Eysenck, 1979, demonstrated that extraverted individuals work more rapidly than introverted persons in dual-task memory scanning experiments). Some of our studies employed the Triplet Numbers and Swaps tests (Stankov, 1983; 1993; Stankov & Crawford, 1993). The most complex versions of these tests measure fluid intelligence. Each more complex version of the task has everything that the lower version has, plus something else. This important feature was not present in the componential approaches that searched for ECTs of intelligence.

Insert Table 2 about here

Stimuli for the Triplet Numbers test consist of a randomly chosen set of three different digits presented simultaneously on the computer screen, and which change after each response. Four versions differ with respect to instructions given to subjects. These instructions make the "Two-rules" version similar to those used in previous psychometric work, while all other versions were used for the first time in the Stankov and Crawford (1993) study. Stimuli for all versions of the Swaps test consist of a set of three letters (J, K, and L) presented simultaneously (letter order is varied from item to item) together with instructions to interchange, or "swap," the positions of pairs of letters. The four versions of the task differ in number of such instructions. After completing all required mental swaps, the subject has to type the final resulting order on the computer keyboard.

Performance on these tests was correlated with measures of Gf and the resulting COSAN confirmatory factor analytic solution (cf. McDonald, 1978), is displayed in Table 2. Important is the pattern of loadings of Gf on the two tasks. In both cases, there is a non-decreasing pattern for Gf loadings, the more complex task is somewhat more closely related to intelligence in these data. There is a less pronounced increase in size of loadings within the two task-specific factors as well. Overall, if we assume that complexity means that many different cognitive processes of Gf are involved, then whatever aspect of processing changes in the two experimental tasks, captures that complexity as well.

Experimental manipulations inherent in the Swaps and Triplet Numbers tests can be understood in terms of capacity theory--either working memory or attentional resources, or in terms of Snow's (1989) interpretation of radex structure. Mental speed seems rather unimportant in these tasks. Clearly, these manipulations have nothing to do with "novelty" or "non-entrenchment" emphasized in Sternberg's (1985) experiential subtheory. A salient feature is the ability to work through a series of steps required for problem solution. The larger the number of such steps, the more likely is the less intelligent person to obtain the correct solution. This interpretation accords with the finding of significant correlations between Gf and several trail-making tests (Vernon, 1992).

Measurement Problem: Personality and Intelligence as a Quantitative Variable

Developments in measurement theory suggest new ways of examining what types of scales are involved in personality and intelligence tests. Conjoint measurement theory suggests a set of conditions that need to be satisfied by a quantitative variable (cf. Michell, 1990). One way to test the quantitative properties of a variable involves arranging experimental conditions in a two-way ANOVA layout. Thus, if we have two independent variables with three levels each, there are nine cells, and conjoint measurement assumptions can be tested. For a 3 x 3 cross, two tests of conjoint measurement need to be carried out. These "independence" and "double cancellation" conditions are illustrated in Figure 2.

Insert Figure 2 about here

Single cancellation means that for any two rows, if a cell in a row is greater than or equal to a corresponding cell in the other row then all cells in that row should be greater than or equal to corresponding cells in the other row. Similarly, orderings between columns of a conjoint matrix should be the same regardless of row. In the top of Figure 2, a single-line arrow indicates that a given cell is greater than another cell. Double-line arrows imply the same relationship should hold for all other cells in a given row or column. Otherwise, the "independence" condition of conjoint measurement is not satisfied. The "double cancellation" condition is illustrated in the lower part of Figure 2. Thus, if the single-line arrows point in a particular direction, the double-line arrow should point as shown.

If both conjoint measurement conditions are satisfied, we cannot reject the assumption that the dependent variable as well as the two independent variables are quantitative. Satisfaction of conjoint measurement conditions suggests that intelligence tests belong to a scale type higher than a simple ordinal scale. It is difficult to classify the IQ scale as either ordinal or interval, and it is better regarded as a "quasi-interval" scale. Likewise, personality inventories with Likert-type response scales are at best ordinal measures, whereas those with dichotomous (e.g., True/False) scales provide categorical measurement, so that statistical analyses of such personality data are necessarily restricted.

In our work, the dependent variables were accuracy and speed scores from the Letter Series test (Stankov & Cregan, 1993). The two independent variables were the number of WMPs and motivational instructions. Thus, subjects must work faster the second time (75% of the original time) and even faster the third time (50% of initial time). Both independence and double cancellation conditions of conjoint measurement were satisfied by the structure on means, for both accuracy and time scores. Therefore, we cannot reject the assumption that intelligence measured by the Letter Series test is a quantitative variable. What happens to the correlation between the scores on the Letter Series test and another test of Gf (Raven's Progressive Matrices) under these treatment conditions?

These correlations are presented in Table 3.

Insert Table 3 about here

Since the pattern of correlations supports both the double cancellation, and independence conditions, the relationship between the two measures may be a quantitative variable as well. We may speculate that factor loadings on these two tests (see Table 2 above) have quantitative properties. Their measurement properties may be stronger than previously realized. As the most systematic increase in correlation is present across rows (Table 3), the increase is in number of WMPs which leads to higher correlations with Raven's test. The pattern is similar to that with the Swaps and Triplet Numbers tests in the previous section. The same explanation--i.e., an increase in number of steps required by the Letter Series tasks at higher WMP levels--may be responsible for the increase. Yet, only the first column shows systematic increase in correlations; the other two columns show about the same size of correlations across rows. Motivation, or asking individuals to work faster, is therefore a poor example of complexity manipulation.

Contributions from Sociological and Anthropological Perspectives

In addition to crosscultural comparisons of performances on traditional psychometric tests of abilities and personality traits, there has been renewed interest in social and "practical" (sic) intelligence. Some studies have suggested the concept of "wisdom" may be more relevant than intelligence in accounting for adaptive behavior in old age. New theoretical work has delineated complex cultural factors that operate to influence the development and expression of intelligence (Irvine & Berry, 1988). Impetus for continuing interest in this interaction was provided by Sternberg's (1985) triarchic theory of intelligence which emphasizes that intelligence is purposively directed toward pursuit of three goals--adaptation to physical and social environment, shaping, and selection of an environment. Despite Margaret Mead's anthropological studies (see Freeman, 1983) being exposed to criticism (information provided for Mead's <u>Coming of Age in Samoa</u> was in fact a joke manufactured by the native teenagers), some crosscultural psychologists have embraced an extreme environmental position on intelligence.

<u>Crosscultural Differences in Traditional Tests of Personality and Abilities</u>

Studies have compared national, cultural and racial groups with respect to mean IQ scores and factor structure of cognitive abilities and personality traits. The validity of these comparisons critically depends on adequate subject selection and test translation. Since these are rarely if ever satisfactory, comparisons are always open to criticism on methodological grounds. Even if there is no need to use words and translate from one language into another (e.g., Cattell's Culture Fair Intelligence Test, or the Queensland Test--designed for testing non-verbal intelligence in desert aboriginees), the nature of the test may change depending on the culture in question and we can therefore talk only about grades of culture-fairness, not about culture-free tests (see Cattell, 1982).

There are three main findings. First, the factor structure of abilities and personality is remarkably similar across different racial and ethnic groups (Cattell, 1987a; Jensen, 1980). Thus, the structure of auditory abilities has been replicated in the USA (Stankov & Horn, 1980), Yugoslavia (Stankov, 1978), and Australia (Stankov & Spilsbury, 1978). Likewise, the 16PF personality structure has been replicated crossculturally (see Cattell, 1973). To some extent, this is due to basic similarities in knowledge and educational practices across the world. This similarity in factor structures breaks down when the focus is on preliterate societies. Second, Cattell and Brennan (1984) gathered data on 80 variables from 110 countries. The variables were indices of integrated national behaviors. Factor analysis of these data produced several so-called *syntality* factors. One of these factors--Vigorous Adapted Development--exhibited a correlation of .34 with the estimated average population intelligence (culture fair). It loads on such variables as level of industrial development, number of patented inventions, Nobel prize winners per 100,000 of population, and so on. Third, small differences between various national-cultural groups are invariably evident, and often the pattern of mean differences reflects the emphasis on particular abilities within the culture.

Practical and Social Intelligence

Wagner and Sternberg (1986) developed a theory of behavior in occupational settings. The theory concerns tacit knowledge about managing oneself, others, and a career. This knowledge is not explicitly taught even though it is important for success in many different work settings. Wagner and Sternberg constructed a measurement instrument that describes work-related situations and asked employees to choose from among alternative courses of action. The instrument has high face validity and may appeal to users of psychological services. Although the test can discriminate between students and professionals and between successful and less successful individuals within the same field, we know little about its predictive validity. However, reported correlations of the test with intelligence measures are close to zero.

The theory of tacit knowledge incorporates ideas considered part of social intelligence (Brown & Anthony, 1990). Overall, there is no clear evidence of noteworthy correlations between different measures of social intelligence. These measures do not correlate better than ordinary intelligence measures with various real-world competencies, and it is not clear how social intelligence differs from certain personality traits such as Sensitivity (16PF Factor I), and/or Shrewdness (16PF Factor N), etc.

Elusive Concept of "Wisdom"

According to Baltes and Smith (1989), wisdom refers to an expert knowledge system--i.e., a highly developed body of factual and procedural knowledge and judgment dealing with the "fundamental pragmatics of life." These concern important but uncertain matters such as knowledge and judgment about the course, variations, conditions, conduct, and meaning of life. Wise people are said to have insight into human development, and exceptionally good judgment about difficult life problems. This view can be traced to the theory of intelligence proposed by Baltes and associates in the early 1980s which distinguishes between "mechanics" and "pragmatics" (or "wisdom"). On closer scrutiny, "pragmatics" appears to reduce to the processes of crystallized intelligence (Gc). Although various personality factors (such as Surgency/16PF Factor F) appear to relate directly to cleverness and a "sparkling wit," there seems to be no necessary relationship with "wisdom," *per se*. Moreover, there is a lack of convincing empirical studies showing the usefulness of distinguishing wisdom from crystallized intelligence.

Degree of Extremism of the Radical Cultural Relativism Hypothesis

Berry (1974) proposed a "radical cultural relativism" hypothesis which rejects the idea of psychological universals across cultural systems. Any behavioral concept applied within the culture is unique to that culture. We can use only indigenous ideas about cognitive competence to describe and assess cognitive capacity. Literal interpretation of this position denies the possibility of crosscultural comparisons. Echoes of this position can be found in studies within our own culture. Thus, Ceci (1990) shows that highly competent behavior within a subculture based on a rather complex knowledge--e.g., successful betting at the horse races--may not necessarily correlate significantly with intelligence test scores--other factors including personality dispositions, and learned behavior patterns may also play an important role. Berry's work does not appear too radical--he has studied cognitive styles, and the so-called differentiation hypothesis that is closely related to visualization (Gv) spatial abilities. Berry points out that the type of society (agricultural, hunter-gatherer) relates to the degree of differentiation achieved by individuals living within a given cultural context. Overall, the work within sociological and anthropological perspectives that has criticized use of traditional intelligence and personality tests for crosscultural comparisons has not produced a successful alternative way of measuring competencies. However, crosscultural psychologists have contributed to improvements in our understanding of cultural effects on intelligence and personality.

Individual Differences and Social Policies, Fashions and Epidemics

Societal Changes and Increases in IQ Test Scores

The first large-scale data linking demographic trends and measured intelligence became available between the two World Wars (see Cattell, 1987a). A more recent study by Vining (1982) supported early findings. Of major concern was the realization that different strata of society exhibit different natality rates with the most educated producing disproportionately fewer offspring than poorly educated groups. This was coupled with improved health care and increased survival rates. These demographic changes, it was feared, could reduce overall level of national intelligence even though available data did not show significant reductions in intelligence between two generations.

In the 1980s large-scale post-WWII data from the USA and Europe became available. Flynn (1984, 1987) reported that scores on Gf tests of intelligence administered in successive years to young people enlisted into the armed services, showed systematic improvements (in excess of 13 IQ points), over the 40-year period (Cattell also obtained a slight increase in IQ scores when he retested the same population 15 years later). Presumably, early predictions did not allow for the diffferential death rate with intelligence (see O'Toole & Stankov, 1992), and the fact that not all people form families. There are two proposed explanations for the reported results. Biologically inclined researchers attribute improvements in intelligence scores to better nutrition in the second half of this century (Schoenthaler et al., 1991). Those who prefer socioenvironmental explanations emphasize improvements in educational interventions among disadvantaged groups. This explanation is supported by work of Kvashchev in Yugoslavia (see Stankov, 1986; Stankov & Chen, 1988).

Interaction of Personality and Abilities in Academic Achievement

While traditional concepts of under- and over-achievement suggest it is feasible to predict academic achievement from intelligence test scores alone, there is no doubt that personality traits interact with cognitive abilities in influencing learning outcomes (Boyle, 1990b). This interaction is probably more important than the role of either abilities or traits alone. The first two 16PF second-stratum dimensions (Eysenck's Extraversion and Neuroticism factors) are particularly influential (cf. Birkett-Cattell, 1989). As Eysenck and Eysenck (1984) have shown, introverted individuals condition more rapidly than extraverts, and their decay of conditioned behaviors is slower than for extraverts. At elementary school, extraverted students perform better, whereas at college level, introverted students outperform their extraverted classmates. While Neuroticism (anxiety) may attenuate learning in intellectually less able students, or those who do not know their work well, it may facilitate performance (serving as a drive) in more intelligent students, and/or those who have more comprehensive knowledge. Thus, anxiety may serve as both a debilitating influence, and as a facilitating factor on performance outcomes. As compared with written take-home assignments, examinations tend to produce a wider range of scores among students. In one study, under conditions of heightened emotionality, no fewer than seven of the 16PF factors were found to exhibit significant correlations with academic performance, whereas only Factor Q_2 (Self-Sufficiency) correlated significantly with learning under neutral emotional conditions (Boyle, 1983). Whereas Intelligence (as measured via the ACER-AL test) correlated .35 with performance under neutral conditions, its magnitude dropped to .21 under heightened emotional activation, and several personality traits predominated over cognitive abilities in influencing learning outcomes. Other non-ability intrapersonal characteristics including motivational dynamic traits and emotional states also contribute significantly to the prediction of academic performance (e.g., Boyle & Start, 1989b; Boyle, Start, & Hall, 1989).

Sex Differences in Personality and Intelligence

Despite attempts by the feminist movement to mimimize sex differences in cognitive abilities and personality, Sandra Scarr (1988) has called for objective scientific research into such differences. Thus, Feingold (1988) compared performances of males and females on the Differential Aptitude Test in successive years between 1947 and 1980. For all subtests, differences between males and females have remained relatively constant with successive generations. In 1947, females exhibited about eight IQ points higher than males on a test of Spelling. In 1980, their superiority was about seven IQ points. For some abilities (e.g., Verbal Reasoning, Abstract Reasoning, Numerical Reasoning), these differences were not significant in 1980, even though some had shown significant differences in the past. Undoubtedly, some of these reductions in significance levels is attributable to the statistical phenomenon of *regression to the mean*. There are clearcut sex differences in abilities however (Eysenck, 1976). As Rushton (1993, p. 231) pointed out, "Women excel in verbal ability, perceptual speed, and motor coordination within personal space; men do better on various spatial tests and on tests of mathematical reasoning (Kimura, 1992)." On Mechanical Reasoning ability, males are clearly superior to females (about 11 IQ points) in dealing with mechanical and spatial problems. Stanley and Benbow (1986) summarized a large number of studies showing a consistently reported superiority of males over females in spatial ability. Benbow (1988) has discussed the role of environmental and genetic factors in accounting for sex differences in spatial abilities (also see Moir & Jessel, 1989).

Bernard, Boyle, and Jackling (1990) explored the relationship between sex-role identity, field independence, and scholastic intelligence. Subjects (140 males; 181 females in grades 11 and 12) completed the Witkin Group Embedded Figures Test, the Otis Higher Test C of intelligence, and a shortened version of the Bem Sex Role Inventory. Measurement of sex-role identity enables assessment of whether higher performance on a test of field independence and intelligence is more a function of masculinity, or sex-reversed sex-role identity. Results showed significant differences in intelligence and field independence among different sex-role groups. Males performed significantly better on the Witkin and Otis tests than did females. Males with lower masculinity scores performed better on the Otis than those with higher scores on masculinity. Females with low femininity scores performed higher on the Witkin and Otis tests than did females with high femininity scores. When subjects were allocated by sex into one of four sex-role identity groups, the most significant difference in intelligence was obtained between the high masculine-low feminine, and low masculine-high feminine female groups, with the former group outperforming the latter. In contrast, highly andogenous (high masculine-high feminine) females did not perform as well as high masculine-low feminine groups. As Bradshaw and Nettleton (1983) pointed out, relationships between social, biological, and hormonal factors among different sex-role groups and mental ability require further exploration.

Sex differences in spatial/mechanical abilities cannot be accounted for by explanations in terms of cultural factors (Moir & Jessel, 1989). Current biological explanations are in terms of (a) Sex-linked gene for spatial ability; (b) Differences in the degree of cerebral lateralization--males are more lateralized than females (Kimura & Hampson, 1992). It is assumed the parietal lobe of the right cerebral hemisphere, responsible for performance on spatial tasks, is better specialized in males than in females. Females use a more "integrated" mode of thinking than males (the corpus callosum connecting the two cerebral hemispheres is larger in females--cf. Bradshaw & Nettleton, 1983; Moir & Jessel, 1989); (c) Hormonal differences, especially androgen/estrogen ratio.

Sex differences on some types of tasks exist in samples that are <u>above or below average</u> in general ability. Even though there is a small overall mean difference between males and females in performance on numerical and mathematical tasks, there is a disproportionate number of males who show high mathematical ability. One explanation is that mathematical ability is dependent on spatial/mechanical abilities. Since males are superior on such abilities, they tend to obtain higher scores on tests of mathematical ability. Another explanation is that small differences in central tendency imply large differences at the extremes of the distribution, given larger standard deviations for males than females. While there may be an insignificant difference in favor of males in overall level of performance in mathematics, there will be a disproportionately large number of males with high and low scores. The difference is therefore due to greater spread of scores among males, not to a manipulation of social conditions in their favor.

With respect to non-ability intrapersonal psychological variables, Boyle and Start (1989b) examined the relationships between motivational dynamic traits (measured in the Children's Motivation Analysis Test or CMAT) to both reading and mathematics performance among Grade 6 children (cf. Boyle & Start, 1989a). Results revealed several sex differences. Likewise, among Grade 10 students, Boyle et al.(1989) observed that males invested a greater proportion of intellectual abilities (measured via the SMAT General Information Intelligence Score) in mathematics learning, whereas females demonstrated a higher investment of cognitive abilities in language learning. However, Boyle (1989c) found few differences in reported mood states among male and female undergraduates. Cohn (1991) undertook a meta-analysis of 65 studies on sex differences throughout the course of normal personality development, and reported substantial advantages for female adolescents on verbal abilities, ego development, moral judgments, aggression, and empathy. According to Cohn (p. 252), "The greater maturity displayed by adolescent girls is not an artifact of superior verbal abilities: Sex differences in ego development were more than twice the magnitude of differences in vocabulary skills (Hyde & Linn, 1988)."

Clearly, there is greater variability among males than females in many psychological traits. There are more males in jails, in psychiatric institutions, in special schools, and so on. At the same time, there is a larger proportion of males than females among high achievers. In many personality traits, the range of scores for males is greater than for females. The variance of males on general intelligence tests is about 10% larger than that of females. Thus, even though means for these two groups do not differ significantly, the spread of scores is clearly different and, as a consequence, one finds more males than females among the high- and low-achieving groups.

Effects of AIDS on Personality and Cognitive Abilities

The AIDS epidemic has increased awareness of the role of immunological factors in psychological functioning. Particularly noticeable is deterioration in cognitive processes among AIDS sufferers, but personality changes (depression) and motor disturbances are also an aspect of the "AIDS dementia complex." Cognitive changes are most salient and the presence of severe dementia is sufficient to make a definite diagnosis of AIDS in a person known to be infected by the human immunological virus (i.e., in HIV-positive individuals).[1]

Soon after HIV infection, the virus enters the central nervous system (CNS) and often penetrates the blood-brain barrier (Resnick, Berger, Shapshak, & Tourttellotte, 1988). It has been suggested that mild cognitive changes associated with the HIV infection may be detected even at the very early stages of the disease. A battery of neuropsychological tests has been suggested (Butters et al., 1990). Apart from the commonly employed measures of premorbid intelligence, memory, abstraction, language and perceptual abilities, the battery includes measures of constructural and motor abilities, and assessment of psychopathology. In recognition of recent changes in studies of cognitive functioning, the battery places particular emphasis on measures of divided and sustained attention, as well as speed of processing and retrieval from working and long-term memory.

The usefulness of clinical neuropsychological and multidimensional personality measures for detection of HIV infection is still being debated. This is partly due to the uncertainty about the nature and timing of alterations in cognitive functions and concomitant personality changes that result from such infection. It is also due to inadequate design aspects of reported studies (i.e., differences between patients and controls in educational background or premorbid psychological status, history of drug use and co-existing medical conditions), and to difficulty in distinguishing between psychological states that result from organic as opposed to non-organic factors. Individuals disgnosed as seropositive for HIV have been found to exhibit a significantly higher degree of AIDS-specific optimism and active coping, suggesting the adaptive role of optimism in situations of potential psychological distress (Taylor, Kemeny, Aspinwall, Schneider, Rodriguez, & Herbert, 1992).

Summary and Conclusions

The multivariate psychometric model remains the main avenue for studying personality and intelligence today. The Cattellian theory of fluid and crystallized intelligence provides a meaningful organization of the body of knowledge on individual differences in human abilities. Although during the past two decades, other approaches have gained in autonomy, not one of them has achieved the status of the Gf/Gc theory. Both normal and abnormal personality traits also are important in influencing behavior, and interact with other non-ability intrapersonal variables (motivation and mood-state factors) and cognitive abilities.

In recent years, the so-called "Big Five" personality dimensions have been "popular." However, these have emerged from analyses of a limited proportion of the normal trait domain, and moreover, have been based predominantly on somewhat unsophisticated factor analytic methods. It has been demonstrated in reanalyses of data by Boyle (1989a) that these personality dimensions represent a rather crude approximation to the higher-stratum factors derived from the more comprehensive 16PF model. The attainment of superior simple structure factors by Krug and Johns (1986) over the NEO-PI or 50-BSRS factors is clear from the considerably higher .10 hyperplane count.

New approaches and models have also enriched our understanding of personality and intelligence by adding concepts not available through traditional approaches, and by asking new questions. On the biological side, exciting avenues have been opened by technological advances in brain imaging and biochemistry. These advances will allow for a better description of the physical and psychobiological correlates of personality and intelligence (cf. Zuckerman, 1991), and therefore enable more precise theories about the mind-body dualism. Also, there is a prospect for using material interventions to improve overall cognitive performance.

Given the strength of reported relationships, it appears that studies relating mental speed to intelligence have been overemphasized. While these studies have shown that mental speed is one of the important aspects of cognitive functioning, further work needs to be done to establish the actual correlations between different measures of speed. Experimental cognitive studies of intelligence have left a significant impact. They have forced multivariate psychologists to look at the microstructure of their tasks and, in the process, have reawakened important questions about the nature of human abilities and the role of complexity. This area will continue to flourish, producing fresh views of intelligence when cognitive sciences reach the next stage of their development. Clearly, such developments must however take into account the important role of personality effects on cognitive functioning. For example, in regard to incidental recall, some evidence (e.g., Bermudez, Perez, & Padilla, 1988) suggests that extraverted individuals perform better than introverted persons, implicating a likely interaction of intelligence and personality.

Studies of intelligence from sociological and anthropological perspectives have been the most disappointing. Apart from defining what we mean by culture in its relation to intelligence, these studies have produced relatively little improvement in our understanding of intelligence. They provide a reminder about the dangers of rampant sociobiological intepretations, rather than truly new information about human cognitive functioning. Clearly, social forces act in setting the agenda for research in intelligence. Societal changes, including the rise of feminism, have affected our research and challenged some of the entrenched views of individual differences, as have concerns about aging populations and the effects of new diseases.

Substantial evidence exists that personality traits and cognitive abilities interact appreciably in modifying human behaviors. These combined effects are most discernible within the objective test (T-data) arena. In the future, considerably greater emphasis should be placed on the *objective* measurement of personality traits, enabling the nature and extent of complex personality-ability interactions to be clarified. Undoubtedly, further research based on new models and paradigms of personality and intelligence will result in considerable new insights.

FIGURE CAPTIONS

Figure 1.

Illustration of the radex structure. Both Guttman and Snow agree about the main elements of the Mode of Expression facet (Verbal, Figural, and Numerical) represented by the slices of the pie. They also agree on the location of the different tests. Their disagreement is with respect to the nature of the processes captured by the concentric circles: the shaded area contains labels suggested by Guttman (Learning, Application, Inference) and the un-shaded area is labeled in accordance with Snow's interpretations.

Figure 2.

Upper Panel: Single cancellation conditions. Column labels W1 to W3 represent levels of the working memory placekeepers (WMP) fact

or, and row labels M1 to M3 stand for the motivation (M) factor. Cells within the cross are defined in terms of the marginal labels. Lines with arrowheads within the cross of W and M illustrate tests of single cancellation. Premises are indicated by the lines and the conclusion is represented by a double line. Basically, satisfaction of the single cancellation condition establishes that cells in all rows and in all columns are ordered in exactly the same way.

Lower Pannel: Double cancellation condition. Column labels W1 to W3 represent levels of the working memory placekeepers (WMP) factor, and row labels M1 to M3 stand for the motivation (M) factor. Lines with arrowheads within the cross of W and M illustrate a test of double cancellation. Premises are indicated by the single lines and the conclusion is represented by a double line.

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ENDNOTE

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