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ABSTRACT

As spinoffs of the current revolution in the cognitive and neurosciences, clinical neuropsychologists in the 21st century will be employing biological tests of intelligence and cognition which record individual differences in brain functions at the neuromolecular, neurophysiologic, and neurochemical levels. Assessment of patients will focus more on better use of still intact functions, as well as rehabilitating or bypassing impaired functions, than emphasizing diagnosis, as is the focus today. Better developed successors to today's scales for assessing personal competency and adaptive behavior, as well as overall quality of life, also will be in wide use in clinical settings. With more normal individuals, use of new generations of paper and pencil inventories as well as biological measures for assessing differences in interests, attitudes, personality styles, and predispositions is predicted. Two figures and one table illustrate the discussion, and a 63-item list of references is included. (Author/SLD)

Psychological Testing and Assessment in the Twenty-first Century [1]

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Running Heading: TESTING AND ASSESSMENT

Abstract

As spinoffs of the current revolution in the cognitive and neurosciences, clinical neuropsychologists in the 21st century will be employing biological tests of intelligence and cognition which record individual differences in brain functions at the neuromolecular, neurophysiologic and neurochemical levels. Assessment of patients will focus more on better use of still intact functions, as well as rehabilitating or bypassing impaired functions, than emphasizing diagnosis as is the focus today. Better developed successors to today's scales for assessing personal competency and adaptive behavior, as well as overall quality of life, also will be in wide use in clinical settings. With more normal individuals, use of new generations of paper and pencil inventories as well as biological measures for assessing differences in interests, attitudes, personality styles and predispositions is predicted.

Psychological Testing and Assessment in the Twenty-first Century

Historical Antecedents

McReynolds (1975, 1986) and several other historians (who are cited in Matarazzo, 1990), quoting from some of the earliest writings of civilization, document for interested scholars that a form of psychological assessment of individuals based on their individual differences in intellectual, personality, and physical traits was being practiced in both Ancient China and Greece as early as some 2,000-2,500 years ago, and during enlightened eras again periodically in subsequent centuries. However, the majority of textbooks recount that today's more systematized and standardized practice of the psychological assessment of individuals began with such modern contributors as Francis Galton in London, Emil Kraepelin in Germany, and Alfred Binet in Paris at the end of the nineteenth century (Matarazzo, 1972; Zilboorg, 1941). Galton published studies of individual differences in mathematics among students at Cambridge University in 1869, followed up with a publication in 1883 on the considerable individual differences in sensory and psychomotor responses he recorded in visitors to London's South Kensington Museum, and in 1884 published an article on the measurement of character and personality along lines which are as fresh today as they were a century ago (Goldberg, 1990). Concurrently, in 1890 one of Galton's students, the American psychologist James McKeen Cattell, published in Mind the first modern, scientific paper on psychological assessment entitled "Mental tests and Measurements."

A second precedent to modern assessment was Emil Kraepelin's publication of a system of classifying individuals with psychological and psychiatric disorders into one of several dozen different types of diagnostic categories (Zilboorg, 1941). Today's Revised Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R) is the current offshoot of Kraepelin's late nineteenth-century system.

The third classical work on psychological assessment began with the ambitious but failed, decade-long program of studies Binet conducted with colleagues during 1895-1904 and which, followed quickly by a series of fortuitous events, culminated in the development of the prototype of all of today's tests for the measurement of intelligence, the 1905 Binet-Simon Scale. When early studies revealed that the scores obtained on the Binet-Simon Scale were valid indices of individual differences in everyday functioning, such as observations by teachers and parents, quality of school work, placement in special education classes or training schools, grades held behind or placed ahead of classroom age-peers in the public schools, and rudimentary judgments of occupational attainment after leaving school, a new profession, that of modern psychological assessment, was spawned.

These century-old successes by Galton, Cattell, Kraepelin, Binet and Simon in the objective appraisal of individual differences in mental abilities, character, and psychopathology soon were built upon by others. Specifically, during 1920-1960 those earlier successes were extended to the assessment of the following. (1) Individual differences in temperament and personality by use of objective and projective tests (e.g. with the development of such tests as the Rorschach, Bernreuter, Thematic Apperception Test, and the Minnesota Multiphasic Personality Inventory). (2) Differences in aptitudes and achievement in children (e.g., with the Stanford Achievement Tests, Scholastic Achievement Test, and Primary Mental Abilities Tests). (3) Individual differences in leadership and related management skills during the latter part of that the same era (e.g. using the Critical Incident Technique, In Basket Technique, Assessment Centers, and others). (4) And culminated (during 1960 - present) in the early successes currently being achieved in the more indepth and focused assessment of cognitive, memory, and related neuropsychological functions (e.g. with the Wechsler Intelligence and Memory Scales, as well as the Luria and Halstead-Reitan Batteries).

Looking back today to when Galton, Kraepelin, Cattell, and Binet and their contemporaries began their studies, it is unlikely that a hundred years ago scientists could have discerned then, let alone predicted, either (1) the human attributes and other domains that by today have become amenable to assessment, or (2) the specific items and content included in the types of tests and techniques that presently are available to help assess individual differences in such a wide variety of traits and characteristics.

Early Twentieth-Century Predictions

Nevertheless, I have been asked to look into a crystal ball and attempt to predict the status of psychological assessment in the twenty-first century (which I will interpret to mean two to three decades from now). It is generally acknowledged that such predictions are more often wrong than right. In fact, the quality of the types of predictions of future developments such as those I have been asked to pen here are known to be notoriously incorrect inasmuch as they are dependent upon technological and theoretical innovations, as well as future changes and developments in the social and political climate of society, that can hardly be imagined, let alone lent credibility, by analyzing only today's trends.

This disclaimer notwithstanding, it is true that occasionally some of these types of predictions have been found to be accurate. Notable examples include predictions regarding the future of clinical and applied psychology offered by two eminent American Psychologists in 1937 in the first issue of the Journal of Consulting Psychology. In the opening article of the first issue of that journal, James McKeen Cattell recalled that in 1917, on the occasion of the 25th anniversary of the founding of the American Psychological Association (APA), he had remarked that although the then 307 members of the APA included 207 teachers and only 16 practitioners, he nevertheless had predicted that by APA's 50th anniversary (1942) the practitioners might surpass the teachers in numbers. Alas, although when writing in 1937 it appeared to him that this prediction would not be borne out by the 1942 time table he had anticipated in 1917, subsequent developments proved that Cattell was correct in 1917 and 1937 in reading the trends in the then-changing demographic mix of APA members. Specifically, today's data from the APA membership office bear out his prediction in that, allowing for the multiple roles of many of them, during APA's centennial year the Association's more than 70,000 regular members and fellows are engaged in the following roles: research (41%), education (49%), health service providers (68%), other applied services (24%), educational services (26%), management or administration (49%) and, finally, other employment activities (18%). Additionally, 62% of these APA members, distributed across all the Divisions of the APA, list that they are licensed or certified by their state as practitioners.

In that same 1937 article, Cattell also accurately predicted that "In the inevitable specialization of modern society, there will become increasing need of those who can be paid for expert psychological advice... (and) in the end there will be not only a science but also a profession of psychology." That prediction also was borne out when in 1945 the newly reorganized APA defined and thereby recognized psychology as both a science and a profession, a characterization of itself that is still apt in 1991.

In 1937, when the membership of APA numbered only some 2,000 psychologists, Cattell's colleague, Robert S. Woodworth, was equally foresighted in the opening pages of that same first issue of the new Journal of Consulting Psychology when he independently and accurately predicted that in the future "...the numbers of psychologists required in the (applied) field will be very great, running up into the thousands and possibly comparable to the membership of a national engineering society." However, Woodworth also predicted in that 1937 article that the application of psychology would retain a single identity. Specifically, he predicted "... that it (applied psychology) will (not) split up into several disconnected specialties, one an adjunct to the school, another an adjunct to the court, another to the hospital, another to industry." Alas, this prediction soon proved erroneous inasmuch as less than a decade later (1946) the American Board of Professional Psychology was incorporated and between 1946-1992 formally recognized and credentialled psychologists to practice in the following specialty-designated arenas of application (Matarazzo, 1987): (1) clinical psychology, (2) counseling psychology, (3) industrial-organizational psychology, (4) school psychology, (5) clinical neuropsychology, (6) forensic psychology, (7) family psychology, and (8) behavioral psychology. Furthermore, one other arena of application, (9) health psychology, appears in 1991 very close to being similarly designated.

With an admiration for Professors Cattell and Woodworth, and a clear conviction that some of my predictions will be wrong, albeit also with the hope that one or another of them might be borne out, I offer the following prognostications regarding possible developments during the next two or three decades in the practice of psychological assessment.

Traditional Psychometric Measures of Intelligence

First, and with a fair degree of confidence, relative to both the content and the approach inherent in the types of omnibus items contained in the first Binet-Simon Scale and retained in each of the large array of its successors during the past 85 years, I predict for the types of today's established individually and group administered tests few radical changes in either the types of tests or test items that will be used in the measurement and assessment of individual differences in mental abilities, as these abilities relate to success in some aspects of everyday living. After numerous failures with countless other types of items Binet stumbled upon classes of verbal and performance items that were infused for the most part with what Spearman (1904) already had begun to identify as a general intelligence factor (subsequently labelled *g*), and such items still make up today's tests for the measurement of intelligence. Thus, after an odyssey that involved almost ten years of failed effort, and through a series of uncoordinated and fortuitous events (for a summary see Matarazzo, 1972, pp. 30-68), Binet identified general classes of items that possessed high face validity (i.e., sampled individual differences in reasoning, judgment, memory, and the power of abstraction) and good concurrent and predictive validity relative to what were easily discernable differences in levels of accomplishment and success in everyday pursuits in school and in the workplace. Therefore, despite their limitations if they are used irresponsibly, and assuming that courts do not outlaw them, I predict that several decades from now tests like the Binet and Wechsler Scales and the Scholastic Achievement Test, as well as offshoots of today's individual and group tests for employee selection, will still be in relatively wide use. Additionally, given the annually increasing percentage of our country's population which is made up of minority groups, I expect those intelligence (and personality, etc.) types of tests also will be being administered in languages other than English (e.g. Spanish and Vietnamese).

Physiological Measures of Intelligence

Beginning with Galton's state of the art but premature efforts with sensory measures, during the past 100 years there have been many attempts to add other classes of items radically different from those included by Binet in his first Scale for the measurement of intelligence and continued in all tests to the present. Most such attempts were unsuccessful. However, as described in more detail below and in studies such as those by Levine, Preddy and Thorndike (1987), or by the authors of each of the individual chapters in the books edited by Eysenck (1982) and edited by Vernon (1987, 1990, in press), recent attempts utilizing very different approaches (i.e., sensory and other physiological indices) than those used by Binet have borne more fruit. Eysenck (1986, 1987, 1988), Jensen (1987, 1991; Kranzler and Jensen 1989), and Vernon (1990;

Vernon and Mori, 1990), provide literature reviews of these more recent successes. Specifically, there is accumulating evidence from a number of laboratories that the scores of individuals who differ on traditional measures of Spearman's *g*, such as their IQ scores on the Ravens Progressive Matrices and the Binet and Wechsler Scales, correlate statistically significantly with their own equally reliable "scores" on measures which also reflect sizeable individual differences in a variety of biological indices. These latter indices include (1) individual differences in the average evoked potential (AEP) index obtained from electroencephalogram (EEG) recordings, (2) individual differences in the durations of reaction times (RTs), including both single and more complex RTs (e.g., discrimination and choice RTs), (3) inspection times, as well as (4) the trial to trial, intra-individual oscillations and variabilities (i.e., standard deviations) in such person-specific reaction times and physiological measures. In addition, the results of early studies suggest that both measures of nerve conduction velocity and of the rate at which glucose is metabolized in the brain also correlate with scores on these traditional measures of IQ.

Two examples (of types 1, 2, and 3 cited above) of these biological correlates of Wechsler Full Scale IQ are illustrative. The first is a study reported by D.E. Hendrickson (1982). The biological measure (see Oken, 1989 for a more detailed description) used by Hendrickson was the Average Evoked Potential (AEP) obtained from each individual's own EEG recording. Figure 1 is a diagrammatic presentation of the resting EEG (to the left of the arrow), followed at point A in this case by an auditory (sensory) stimulus introduced by the investigator and reacted to cortically by the subject as he or she processes the stimulus just presented. Averaging the series of EEG waves following the stimulus, negative and then positive in each case, produces the average evoked potential for this individual, a wave process that gradually dies out after something like 750-1000 milliseconds. In Figure 1 successive negative and positive EEG waves are labelled N_1, P_1, N_2, P_2, etc. and are averaged to produce a biological index (AEP), which differs from person to person but which, although it is variable from trial to trial, nevertheless yields a reliable (stable),

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Insert Figure 1 about here

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idiosyncratic index for each individual when averaged across trials.

In his investigation Hendrickson studied a sample of 219 older adolescents (121 boys and 98 girls), to each of whom he administered both a Wechsler Adult Intelligence Scale (WAIS) and an EEG which produced the basis for the second measure (AEP). From the latter Hendrickson derived two additional scores: (1) the trial to trial standard deviation or variance of the AEP as each individual focused attention and processed the auditory information before executing a choice response; and (2) the complexity of the AEP waves the individual produced while executing that cognitive task.

Hendrickson's remarkable findings are presented in Table 1. The results in the bottom row show a high correlation between Full Scale IQ and both the (1) variance measure (-.72) and (2) the complexity measure (.72), each derived from the average evoked potential from the EEG of the same individuals. Equally striking are the correlations shown in the table between these

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Insert Table 1 about here

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two biological measures and each of the eleven subtests of the WAIS. In a study explicitly designed as an attempt to crossvalidate these Hendrickson findings, Stough, Nettelbeck, and Cooper (1990) also found high correlations between their Average Evoked Potential measures and the same individual's score on Verbal IQ (VIQ), Performance IQ (PIQ), and Full Scale IQ (FSIQ) as measured with the Revised WAIS. These latter findings, plus those of Hendrickson shown here in Table 1, thus appear to suggest that each of these EEG measures is almost as robust a measure of Spearman's *g* as are the Binet, Wechsler, and many group administered paper and pencil tests of intelligence currently in use. Furthermore, in his review of this literature Jensen (1987, pp. 105-106) underscores the results of a study by Eysenck and Barrett (1985), independently crossvalidated in a study by Schaefer (1985), in which Eysenck and Barrett reported that the *g* loadings of the WAIS subtests showed a rank-order correlation of +.95 with the correlations of each of the 12 WAIS subtests with the AEP. However, in a study designed as a replication of those 1982 Hendrickson findings, Barrett and Eysenck (in press), were able to duplicate only the main thrust (but not all) of the findings shown here in my Table 1; thus underscoring how such research on EEG correlates of IQ is still in its relatively early stages.

The second example is from a recently completed study by Reed and Jensen (in press) and involved an investigation of the relationship between an individual's IQ on the Ravens Advanced Progressive Matrices test and his independently determined average cerebral evoked potentials following the presentation of a visual stimulus. The investigators used 147 male undergraduates from each of whom they obtained short-latency visually evoked potentials (in response to a visual pattern-reversal stimulation task) recorded over the primary visual cortex. Dividing each subject's head length by the average latency of his visual evoked potential (VEP) provided a measure of each person's visual neural conduction velocity (NCV) as nerve impulses (of 70 to 100 milliseconds) were transmitted from the retina through the visual tract to the visual cortex. After correction for restriction in range, this nerve conduction velocity measure (V: P 100) for a group of visual evoked potentials averaging about 100 milliseconds showed a statistically significant correlation (+ .37) with each person's Raven Matrices IQ score. In order to present the same findings diagrammatically, the distribution of the neural conduction velocity (NCV) measure from the 147 undergraduates, which ranged from the lowest (1.75 meters per second) or least efficient, to the highest (2.22 meters per second) or most efficient, was divided by Reed and Jensen into quintiles, each containing 20 per cent of the students. Averaging the Raven IQ scores for students in each nerve conduction velocity quintile, Reed and Jensen diagrammed the results as shown in Figure 2. Specifically, for the five groups of subjects with progressively and increasingly more efficient neural conduction velocities during the processing of the visually presented pattern-reversal information tasks, the average IQ scores were 114, 116, 117, 121 and 122, respectively. Whether these Reed and Jensen results are visually emphasized by representing them

Insert Figure 2 about here

diagrammatically as was done in Figure 2 by the authors (Jensen, 1991; Reed and Jensen, in press), or more precisely by reference to their own reported Pearson correlation of +.37, these findings by Reed and Jensen appear as remarkable as those of Hendrickson's shown here in my Table 1. However, to add credence to their robustness, Vernon and Mori (in press), in a study of conduction velocity in the median nerve of the arm, found a correlation of +.42 (and +.48 in a crossvalidation sample reported in the same paper) between Full Scale IQ and nerve conduction velocity. Although lower in magnitudes than those reported by Hendrickson and shown here in Table 1, Vernon and Mori also found significant correlations between their arm nerve conduction velocity measures (as well as their reaction time measures) and scores on the individual subtests of their multiple choice variant of the WAIS. Nevertheless, it is necessary to emphasize that research in this area is still in its beginning stages. Specifically, other investigators have not confirmed these Vernon and Mori findings. Thus, although Barrett, Daum, and Eysenck (1990) found a statistically significant correlation of -.44 between the variability of the averaged sensory nerve action potentials in the hand and Ravens IQ score in 44 subjects, in a study by Reed and Jensen (1991) which preceded that Reed and Jensen (in press) study depicted here in Figure 2, the latter reported that they failed to find a correlation between nerve conduction velocity in the arm and IQ score. The thrust of most of the findings is clear, however.

Some two decades ago when I first began to read the findings from studies of the types represented here in Table 1 and Figure 2, I was very skeptical and I had remained so until recently. However, the increasing numbers of such studies, as well as the duplication of the positive findings in many (albeit importantly not all) laboratories from different parts of the world (e.g., see the literature reviews cited above and the meta analysis of many such studies by Kranzler and Jensen, 1989), plus what I will describe below, lead me to believe that, during the next several decades, some such biological correlates will have been shown to be valid measures of what is measured by traditional IQ tests.

Therefore, I predict that we should expect in the decades ahead additional technological advances in both how and what EEG and other biological parameters of individual differences in the measurable aspects of intelligence are recordable. It is reasonable to expect that the technology for measuring these neurophysiological parameters of simple and more complex information processing activities, as well as their executed end-stage target behaviors, also will be improved considerably in the not too distant future. For example, as I will discuss below, I anticipate such improvements will come from the development of new generations of neurophysiological, neurochemical, and neuromolecular measures of information processing and related aspects of cortical functioning, as well as from insights yielded by new generations of advanced systems of brain imaging techniques such as successors to today's Positron Emission Tomography (PET). The types of technological measuring advances I anticipate decades from now are discernable from a pilot study with eight volunteers using PET by Haier, Siegel, Nuechterlein, Hazlet, Wu, ɿek, Browning, and Buchsbaum (1988). These authors reported significant negative correlations between glucose metabolic rate in the brain and a measure of abstract intelligence from the Raven's Advanced Progressive Matrices test, a finding indicating that the individuals who obtained the best scores on the Ravens intelligence test actually expended the least brain energy while responding to the items that comprise that test of intelligence. To test their hypothesis of such smaller brain energy expenditure by more able people, Haier, Siegel, MacLachlan, Soderling, Lottenberg, and Buchsbaum (in press), next measured the rate of glucose metabolism in the brain on two occasions. Glucose measurements were made (a) during the initial trial when their 8 male subjects first began to learn (using the computer game, Tetris) a complex video learning task and (b) again during the very last trial after 4-8 weeks of daily practice of that complex video game skill. The results for the 8 subjects indicated that, over the 4-8 week period of practice, metabolic rate measured in surface regions of the brain decreased despite a more than sevenfold average improvement in game performance skill on that learning task. Furthermore, subjects among the 8 who improved their performance the most after practice on this visuospatial learning task showed the largest glucose metabolic decreases in several areas of the brain. Haier and his colleagues interpreted this finding to suggest that the learning of such a motor response is associated with a decreased use of extraneous or inefficient brain areas. In a further test of their hypothesis, Haier Siegel, Tang, Abel, and Buchsbaum (in press), correlated the scores earned on both the Wechsler Adult Intelligence Scale-Revised (WAIS-R) and on the Ravens Advanced Progressive Matrices Intelligence test by each of these same 8 subjects with measures of rate of glucose metabolism in the brain of the same individual. That study yielded statistically significant findings to support their brain efficiency hypothesis. Specifically, they found that individuals who score highest on measures of intellectual ability (or learn better), also expend lesser amounts of brain energy than do individuals who are not as able. These IQ findings also supported their evolving belief that learning is correlated with the rate of glucose metabolism in some brain regions and not in others.

These findings by Haier and his colleagues are consistent with those reported from other laboratories. Specifically, a study by Parks et al (1988), utilizing sixteen normal volunteers, and correlating a PET measure of glucose metabolic rate in the brain with the individual's score on a neuropsychological test of verbal fluency, also yielded a negative correlation between glucose metabolic rate in the brain and verbal fluency (i.e., the number of words beginning with different letters produced by the individual during each 60-minute trial). Other studies which have reported significant correlations between rate of metabolism and measures of IQ are summarized by Eysenck (1987, p. 53-55), and many other studies reporting statistically significant correlations between the PET and intelligence types of measures are included in a literature review of this small body of studies by Haier (in press).

As an addition to the opinions I stated above that I believe biological indices of intelligence are becoming available, I also predict that such indices of brain function are likely to be complemented by measures of brain structure using future generations of modern imaging technologies. Thus, even today, Willerman, Schultz, Rutledge, and Bigler (1991), after controlling for body size, reported a correlation between brain size and WAIS-R IQ of +.65 in men (N=20) and of +.35 in women (N=20), and a correlation of +.51 for both sexes combined. A further statistical correction for the sample of 40 college students involved indicated a brain size-IQ correlation for both sexes combined of about + .35 in a more representative sample. A follow up analysis of the same 40 subjects by the same authors (Willerman et al. in press) suggested that in men a relatively larger left hemisphere predicted better WAIS-R subtest verbal than nonverbal ability, whereas in women a larger left hemisphere predicted relatively better nonverbal than verbal ability. Obviously, the small Ns involved require crossvalidation of such results. Nevertheless, as increasingly refined neuroimaging technologies become available, other structural features of the brain in studies utilizing larger Ns, etc. undoubtedly will become targets for assessment and, I predict, will be shown to correlate significantly with aspects of intellectual (if not also personality) functions.

Therefore, another of my predictions is that in the early decades of the twenty-first century we may see the further development and use in practice of these and other biological indices of brain function and structure in a test (or a test battery) for the measurement of individual differences in mental ability, thus heralding the first clear break from test items and tests in the Binet tradition in a century. That is, after the appropriate validation studies, and reasoning from the types of results just described as well as those shown here in Table 1 and Figure 2, I believe we may see the development of a new test (or a battery of new tests) for individual examination made up only of biological measures of cortical functioning which will have been found to predict, as well as do today's tests, success in school, as well as occupational attainment and other aspects of everyday living. However, unless technological advances in miniaturization, as well as other inventions and developments relating to the practicability of administration (including social acceptability), also occur, I do not foresee the substituting of such biological tests for the group administered tests today used in our schools and industry. However, the use of such new biological measures of ability by a school psychologist or clinical neuropsychologist providing diagnostic and rehabilitative help in the individual case (e.g., to a brain injured adult or a dyslexic or other learning disabled child) is much more likely, in my opinion, than is their larger scale use with normal groups of children or adults. For example, even at this early date, Michael Posner and Marcus Raichle and their associates, by use of PET imaging are identifying the complex, apparently localized, neural networks in the brain (e.g., an anterior attention system) which are activated when humans cognitively process single words (Posner, Petersen, Fox, and Raichle, 1988; Petersen, Fox, Snyder, and Raichle, 1990). The implications of their research (as well as that of the investigators cited earlier) for the assessment of individual differences in cognitive ability, as well as understanding their biologic correlates, appear extraordinary to me.

Cognitive Psychology and New Tests of Intelligence

In still another area I also predict that, although the individual items making up Binet and Wechsler type intelligence tests will continue to a relatively large extent to reflect Spearman's *g*, we shall see during the next decade or two a refinement in psychometric approach and methodology vis-a-vis the type of items utilized which also borrows heavily from the recent knowledge explosion in cognitive psychology, information processing, and developmental psychology. Breaking new ground, research has been published during the past decade on the elemental components involved in the cognitive strategies utilized by individuals who score high and who score low in the verbal, numerical, conceptual, and other types of domains of mental ability assessed by today's intelligence tests. That research is helping a new breed of investigators such as John B. Carroll, Earl Hunt, and Robert J. Sternberg (see examples of their work in Sternberg, 1985) develop techniques with which to study the first order, mental processes associated with simple as well as increasingly complex levels of human cognitive skills such as reasoning, comprehension, and understanding. Thus, these studies of models of how information from each test item is processed (while a person is engaged in solving the omnibus types of items that mirror individual differences in Spearman's *g*) are providing a fresh approach by which to dissect such reasoning and other skills into their more basic component parts, and thus is helping us better understand the step-by-step cognitive processes individuals utilize in providing the correct answer to some of the individual items which make up the verbal and performance subtests included in today's intelligence and aptitude tests.

I do not believe it is anticipating too much to expect that, in the next several decades, one may see an integration into a single model of brain functioning (a) the above cited works of Carroll, Hunt, Sternberg and others who are proposing new theories of intelligence, with (b) the biologic substrates for cognitive functioning now being identified and studied by Posner, Raichle, Vernon, Haier, Jensen, Hendrickson, Eysenck, and the others I cited earlier. When this occurs it will have provided critically important empirical support for such biological theories of intelligence as proposed (but inadequately validated) a half century ago by Lashley (1929), by Hebb (1942), and by Halstead (1947).

In addition, it is my belief that from this research in cognition and information processing will come not only new items but also new forms of individually administered intelligence tests of a type never before available in tests of ability, including tests made up completely of new types of verbal and performance items. A hint is provided by Das and his colleagues (Das, Kirby, and Jarman, 1979; Naglieri and Das, 1990), who have conceptualized the four basic processes involved in cognition as Planning, Arousal-Attention, Simultaneous, and Successive Information Processing, and who have selected several tests which appear to mirror these processes from both Luria's neuropsychological approach as well as studies in cognitive psychology. Furthermore, these new forms of individual tests I am anticipating may also include still other new types of test items tapping reaction time, and other physiologic measures of mental processing speed of the type that I described above. Regarding the latter, advances that already have been made (in adapting microcomputers for recording and analyzing the concrete cognitive steps chosen in arriving at an answer to items currently included in ability tests) will facilitate our better understanding of some of these complex biological-psychological-behavioral processes whose end products are mirrored as individual differences in IQ and related measurable cognitive capacities.

I am aware that, even taken en toto, the types of studies to date that I identified above which are attempting to identify biological correlates of intelligence and related cognitive processes will appear to some readers as still too few for me or anyone else to predict the anticipated breakthroughs during the next several decades which I cited above. However, although I admit the volume and quality of these works is not enough to garner a high degree of consensus within the community of psychologists, and acknowledging the problem of small sample sizes, the possibility of spuriously significant correlations from the large numbers computed, and other methodological problems, reading this literature in one sitting has left me more optimistic than I was a decade ago.

Improvement in Tests of Neuropsychological Functioning

In other areas relating to the assessment of cognitive abilities I feel fairly confident of another prediction. In today's clinical neuropsychological practice (Matarazzo, 1990) all our most commonly used tests of cognitive and mental ability measure primarily verbal and motor skills which mirror Spearman's *g*; although I acknowledge that a few tests of sensory acuity also account for a small percentage of the remaining variance. However, I anticipate that the next several decades will see the development of better individual tests, as well as successors to the batteries of neuropsychological tests such as the Halstead-Reitan, etc. with which to measure the much more highly specific brain-behavior functions associated with brain injury and subsequent recovery. That is, improving upon the current technology represented here in Figures 1 and 2, as well as the PET imaging measures being used in studies by Haier, Posner, and Raichle, and others which I cited earlier, and expanding a bit on what I stated above, I believe that in the coming decades we will see the development of entirely new neuropsychological batteries composed of items (or whole tests) that will less crudely and more validly than today measure the following. (1) Efficiency in receiving information via different sense modalities. (2) Ability to hold that information in immediate storage (capacity for attention and concentration). (3) Efficiency in processing that information. (4) And then, ability to execute the verbal or motor operations required to complete one's response to the item presented. Albeit acknowledging that different areas of the brain are functionally interrelated, I also predict that such technology will allow us, even better than is done in good studies today (see the PET with WAIS study of Chase et al, 1984), to assess such specialized mental functions as those which relatively are associated more with the frontal versus parietal lobes, as well as assess other specialized cognitive-behavioral functions postulated to be associated with still other specific brain areas. The more recent PET scan studies of brain metabolic rate by Posner et al (1988), and Petersen et al (1990), Parks et al (1990), and by Haier et al (1988, in press) which I cited earlier are examples of an approach seeking to localize in specific areas of the brain the cognitive processes associated with reading, abstract reasoning, visual spatial reasoning, etc. Thus, I foresee an additional application into the clinical domain which involves an offshoot of a marriage of the two quasi-independent advances I described above. Namely, for practical clinical application in neuropsychology, I predict a melding of assessment approaches which incorporates elements from both (a) the new types of biological tests of intelligence described here and in the reviews by Jensen (1987), by Eysenck (1987), and by the authors of individual chapters in Vernon (in press), with (b) the new types of information-processing test-items that I envision conceivably will be developed further by Sternberg, by Posner, and by the others investigators I cited above.

As an example of a clinical application, I believe that the neuropsychological tests of the future will provide more sophisticated analyses of the component processes underlying various cognitive functions, especially with the increasing numbers of elderly individuals in society with Alzheimer's Disorder, as well as with impaired younger patients. One such approach is already being used in a new memory test developed by Delis and colleagues (Delis, Kramer, Kaplan, and Ober, 1987), called the California Verbal Learning Test (CVLT). In addition to assessing overall levels of recall and recognition, the CVLT is designed to measure numerous components of memory, including encoding, storage, and retrieval processes, vulnerability to proactive and retroactive interference, and use of effective or ineffective learning strategies. In initial studies these multiple indices have yielded very high hit rates (97%) for discriminating between normals and patients with Alzheimer's dementia, as well as between patients with different types of dementia (e.g. the 85% hit rate with Alzheimer's and Huntington's disease patients reported by Delis et al., 1991). When from further research the necessary requirements of sensitivity, specificity, and related psychometric requirements are met, and such studies are independently crossvalidated, and the next generation of neuropsychological tests such as the CVLT are used in conjunction with advanced neurophysiological and neurochemical techniques, researchers and clinicians will be able to map more precisely the relationship between patients' spared and impaired cognitive processes and the integrity of specific brain regions. Studies using PET neuroimaging currently underway in the clinical laboratories of the National Institute of Mental Health (Karen Berman, personal communication) offer an example. Her studies clearly reveal that the information processing functions involved in solving the abstraction-type items making up the Wisconsin Card Sorting Test (WCST) take place primarily in the frontal lobes. The studies of Posner and Raichle and their associates showing that reading activates an anterior brain attention system is another example demonstrating how such specific cognitive functions are being localized in the brain. The study by Ober, Jagust, Koss, Delis and Friedland (1991), indicating which parts of the left and of the right brain hemispheres showed increases in glucose metabolism while individual patients were completing a visuoconstructive (drawing) test, is another example of findings localizing cognitive, neuropsychological processes in specific brain regions.

New Tests of Personality and Individual Predispositions

I turn now, and much more briefly, to future developments in the psychological assessment of personality and other noncognitive human characteristics.

Overall, and as with the assessment of intellectual abilities, I anticipate that there also will be many advances in the assessment of personality, temperament, individual predispositions, and related behavioral domains of human functioning. However, inasmuch as I have followed that literature less closely than I have that involving measures of cognitive functioning, I merely will present, without as much elaboration, my prognostications of what the advances in those domains might be.

First, and given its successful use in clinical practice with psychologically-impaired individuals I predict that several decades from now newer inventories as well as restandardized generations of today's version of the Minnesota Multiphasic Personality Inventory (MMPI) still will be in wide use as broad band (generalized) measures of psychopathology. In addition, I also anticipate the development and relatively wide use of tests for the diagnosis and assessment of the more specific forms of psychopathology, such as tests with which to diagnose a panic, or a depressive, or other specific type of disorder. These new generations of tests which I anticipate for diagnosing specific types of disorders and related psychopathology will continue to consist of clusters of MMPI-type items comparable to those for diagnosing mood disorders in current use; e.g., refinements of items in the current Beck Depression Inventory (BDI), and items identifying other specific disorders such as alcoholism and substance abuse. Such disorder-specific psychological tests (or their operationally derived clinical interview equivalents) will be made up of better developed and validated psychological test items and interview probes than are available today, and will have been drawn from the by then further improved, operationally defined, behavioral descriptions contained in future generations of diagnostic systems such as today's

DSM-III-R. I also believe that, by use of the twenty-first century successors of today's Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) technologies, in the near future these new generations of DSM-type diagnostic systems themselves, as well as their psychological test counterparts, will have been better validated by advances which will occur in the differential neuroimaging of the biological correlates of the commonest disorders. Examples of these latter include panic disorder (Reiman, Raichle, Robins, Butler, Herscovitch, Fox, and Perlmutter, 1986), and schizophrenia (Suddath, Christison, Torrey, Casanova, and Weinberger, 1990).

Second, in the personality sphere, and for use with the relatively larger group of more normal, less psychopathologically-impaired individuals, I again anticipate more extensive utilization by tomorrow's practitioners of new generations of inventories. For example, the NEO Personality Inventory developed by Costa and McCrae (1988) for the assessment in healthy individuals of something akin to today's five basic dimensions of character and personality which have evolved empirically from a line of inquiry first suggested by Galton a century ago. Such dimensions were studied fifty years ago by G.W. Allport, and recently were reviewed, improved upon, and further extended by Goldberg (1990). After the more meticulous testing of their theoretical and empirical underpinnings as suggested by Eysenck (1991), I believe tomorrow's offshoots of the NEO Personality Inventory also will be broad band personality and character inventories for normals comparable to what I predicted above will be new generations of broad band MMPI-type tests for examining individuals with psychopathological conditions. Additionally, and as described above in relation to the latter, I also expect several decades from now a relatively wide usage of tests, and interview equivalents, with which to assess more specific psychological styles and predispositions among subgroups of this relatively larger, more normal spectrum of individuals. As examples of the latter, I anticipate much wider use by clinicians (and other practitioners) of tests for assessing twenty-first century, counterpart measures of such physical and psychologically related phenomena as the following being assessed today: (1) the Type A Behavior Pattern; (2) Hostility In and Hostility Out; (3) Hassles in Everyday Living, (4) Optimism Toward One's Own Health, and (5) numerous other measures of generalized levels of psychological and physical well being.

Furthermore, given the advances on the horizon for the potential diagnosis by PET and other brain neuroimaging techniques of the biological correlates of levels of anxiety, obsessive behavior, and related personality dispositions, I predict in the not too distant future the identification of biological indices of (minor, nondisabling levels of) these phenomena in "normal" individuals not unlike the neuroimaging correlates I predicted above for more validly identifying schizophrenic, and panic types of disorders. As will be the case in the latter area of psychopathology, the discovery of these biological indices of more normal personality predispositions should enhance the refinement of future generations of tests such as the NEO, and vice versa. An example of the types of studies I anticipate is that by Haier, Sokolski, Katz, and Buchsbaum (1987) of nine normal volunteers who were administered the Eysenck Personality Questionnaire as well as the Zuckerman Sensation Seeking Scale, with the scores from each test correlated with each individual's own brain glucose metabolic rate as measured by PET scan. The statistically significant, brain area and personality correlations observed suggest to me that this type of research will show considerable growth.

Assessing Personal Competence and Quality of Life

I also anticipate that there will be developed new families of adaptive rating scales and related tests with which to assess additional important psychological characteristics of individuals other than those characteristics of persons demonstrating only psychopathology of the types today catalogued in DSM-III-R. As an example, I believe that school and clinical neuropsychologists of the future will be doing less of today's types of purely diagnostic assessments for the presence or absence of mental subnormality or brain injury. Rather, as I suggested above one of these newer domains will involve what I anticipate will be the assessment of which brain systems and functions are still intact (see Ober et al, 1991 for an example). And, stemming from that perspective I predict there will be developed newer and better generations of today's approaches to the psychological assessment of personal competence in adapting to one's society (Sundberg, Snowden, and Reynolds, 1978). For children in the lower ten to twenty percent of ability groups, rather than involving only assessment of their ability to pass a test of intelligence or achievement or cognitive functioning above a certain cut off level, I believe these better measures for appraising individual competence will include improved generations of today's adaptive behavior scales for assessing the level to which a child has acquired or regained the real world skills needed in everyday living. Thus, in several decades considerably better assessed than today will be a child's skills in grooming, dressing, basic health care, communication, relevant components of reading, writing, and arithmetic, self-direction, responsibility, socialization, making purchases, etc. For young adults in the very lowest ranges of ability, including those graduating from vocationally-oriented high schools and others entering the work force for the first time, comparable, considerably improved future rating scales also will assess equally important adaptive skills (i.e., skills directly related to the jobs to be performed) and will place relatively less emphasis (albeit some) on scores earned on purely intellectual or other neuropsychological measures.

However, as we enter the next century social forces now in evidence will markedly impact psychological practice inasmuch as psychological assessment is inevitably linked with changing needs of society. A number of obvious problems of today will require attention in coming decades. Examples include problems related to alienation and lack of jobs among the American "underclass"; appropriate assessment procedures to use with the rapidly increasing number of minorities; the seemingly large increase of anxiety and depression in American society; and problems related to the growing number of elderly as the post World War II baby boom ages. New and practical measures of assessing coping are likely to be useful in coming decades on both the individual and community levels. These will require and include not only the adaptive behavioral measures cited above, but also cognitive problem-solving assessment focused on how people with different cultural and educational backgrounds think and solve problems. Such real life adaptive-competency measures conceivably will be potentially dynamic and interactive with the major environments in which people live. In addition, future assessment psychologists quite likely will measure changes over time and not examine persons during only a single session. Just as on-line, physiological indices of cardiac functioning during every day activities can now be monitored, I believe that considerably more sensitive tests of psychological states will have been developed to better assess, over time, levels of stress and coping by both impaired and more healthy individuals.

As it becomes more apparent that it is impossible for health service providers who are helping only one individual at a time to achieve any significant inroads in the major psychological problems of society, I anticipate there will be more effective techniques than available today for the prevention of psychological disorders and the promotion of psychological well-being and quality of life. The implication for future psychological assessment of the greater emphasis on prevention is that today's measures for assessing only individuals will not be enough. I therefore anticipate that during the next several decades procedures for the assessment of families, groups, organizations and community areas that are at risk will have been developed and fine-tuned. Thus, I predict that assessment of an individual which is relatively devoid of assessing his or her human and environmental context will, in the coming years, be supplemented by a focus on each individual's "ecology."

Finally, for the hundreds of thousands of individuals from the whole spectrum of level of ability who are disabled with a chronic medical disorder or condition (e.g., one leading to a liver or heart transplantation) or who are injured annually, I expect the development and wide use by rehabilitation psychologists and clinical neuropsychologists of new types of tests for the psychological assessment of quality of life in everyday living. Over a decade ago, Flanagan (1978) described such a test for use with community living adults spanning an age range from 30 to 70 years of age. Other investigators began using his scale or variants of it for assessing the impact on the quality of life of patient samples. Today such scales are being used to assess the quality of life of patients with such chronic conditions as diabetes mellitus, ostomy secondary to colon cancer, osteoarthritis, and rheumatoid arthritis (Burkhardt, Woods, Schultz, and Ziebarth (1989); as well as patients who have received a transplanted liver (Tarter, Switala, Arria, Plail, and Van Thiel, 1991).

I therefore anticipate in the near future better types of quality of life and adaptive behavior scales than the crude ones now available. These will include improved and better standardized scales for assessing degrees of ability in self management in such important daily living skills as pouring a cup of coffee, opening a sugar packet, personal hygiene, dressing, communicating with significant others, cooking, dialing a telephone, reading a menu, ambulating, taking a bus, driving a car. handling personal finances, socializing, returning to work (part or full time and with or without restrictions), engaging in leisure activities, etc. Such better adaptive behavior and quality of life scales also will be widely used in the next century to evaluate the present capacity, as well as the potential for full or partial independent living, of younger and older individuals following a severe orthopedic or brain injury. They also will be in wider use for assessing the present capacity and potential of 65 year and older senior citizens who are experiencing memory as well as physical health problems, and who all estimates suggest will comprise 25 percent of the U.S. population in the year 2040. As detailed in books such as those of Tupper and Cicerone (1990) and Spilker (1990), many of these quality of life scales for use with brain injured patients currently are in the early stages of development. Although still in their infancy, the dimensions of personal adjustment and quality of life which such scales already are attempting to assess is impressive and, thus, I predict that in the first half of the next century new generations of better scales of adaptive behavior relating to the quality of life will be in wide use.

However, as noted above, when such scales are in wide use practitioners of neuropsychological assessment and intervention, for example, will have moved from today's predominant concern with deficits to the assessment of intact brain systems and their associated residual cognitive abilities. In order to do this, and building on the contributions from the advances in the cognitive and neurosciences I predicted earlier in this paper, scientists will by then better understand how basic, component skills are integrated within more molar, complex patterns of every day routines and activities. This shift toward assessment at this level of analysis of functional competencies and quality of life will have required, as I stated above, that we by then are more effectively than today able to assess such an impaired person's environment in order to identify specific barriers and supports which are available or possible. Concurrent with this emphasis on the more focused ecologically-valid measures which I am predicting will have been developed, there very likely also will have been developed psychological measures of such an impaired individual's subjective (meta cognitive) levels of awareness of which of his or her functions are intact and which still are impaired. I anticipate comparable developments in the assessment of such enduring residual feeling states in patients who are undergoing rehabilitation following liver transplantation or following treatment for the types of other chronic medical conditions I cited above.

Computerized Assessment Interpretation

Along with my belief that the current cognitive revolution in the neurosciences in the not too distant future will help identify some of the neurobiologic substrates of general mental ability, I also predict that advances in the technology for administering, as well as the better validity studies needed for interpreting computerized versions of the Binet and Wechsler types of tests of intelligence (as well as personality and other human traits), will wed these latter types of traditional tests into batteries which also contain the new Sternberg et al generation of artificial intelligence, computer modeling and information processing types of tests, thereby improving both theory and psychological practice. Additionally, the breakthroughs in electronic retrieving, processing, communicating, and recombining information, which today is in full bloom in areas outside of psychology, cannot but have a major impact upon psychological assessment in the coming era.

Thus, despite the unease I expressed beginning a decade ago about the misuses and abuses associated with computerized interpretations of psychological tests (Matarazzo, 1983, 1985, 1986), I predict that the requisite validation research will have been published during the next several decades to make such computerized psychological assessment both practical and socially responsive. Specifically, and integrating much of what I included above, I anticipate that with today's improving software and the use of that future era's related information processing technology, clinicians will be employing a multifaceted battery which combines data from a variety of sources into a product that is a skillfully integrated psychological-behavioral profile of the individual (Matarazzo, 1990). I predict that these highly computerized assessments will start by combining into a beginning meaningful whole salient information from the individual's educational, occupational, social and medical histories, and then add to and integrate into that whole equally relevant input consisting of observational-interview data plus the findings from a battery of tests (including biological) that tap intellectual, attitudinal, interest, personality, neuropsychological, adaptive behavior, and quality of life functions. Even now the software for interpreting the findings from the Wechsler Intelligence Scale for Children - III (WISC-III) is being programmed to allow such integration of relevant data from the examinee's social-educational and adaptive history with the relevant WISC-III subtest and total scores.

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Footnotes

1. Editor's note. Articles based on APA award addresses that appear in the American Psychologist are scholarly articles by distinguished contributors to the field. As such, they are given special consideration in the American Psychologist's editorial selection process.

2. The author of this article received the 1991 APA Distinguished Professional Contributions to Knowledge Award. At the invitation of the APA Centennial Task Force, a short version of this article was presented at the 99th Annual Convention of the American Psychological Association in San Francisco in August, 1991.

3. Correspondence concerning this article should be addressed to Joseph D. Matarazzo, School of Medicine, Oregon Health Sciences University, Portland, Oregon 97201.

TABLE 1

Correlations between the WAIS tests, and the Variance. Complexity and Combined Score on the Evoked Potential in the Hendrickson study.

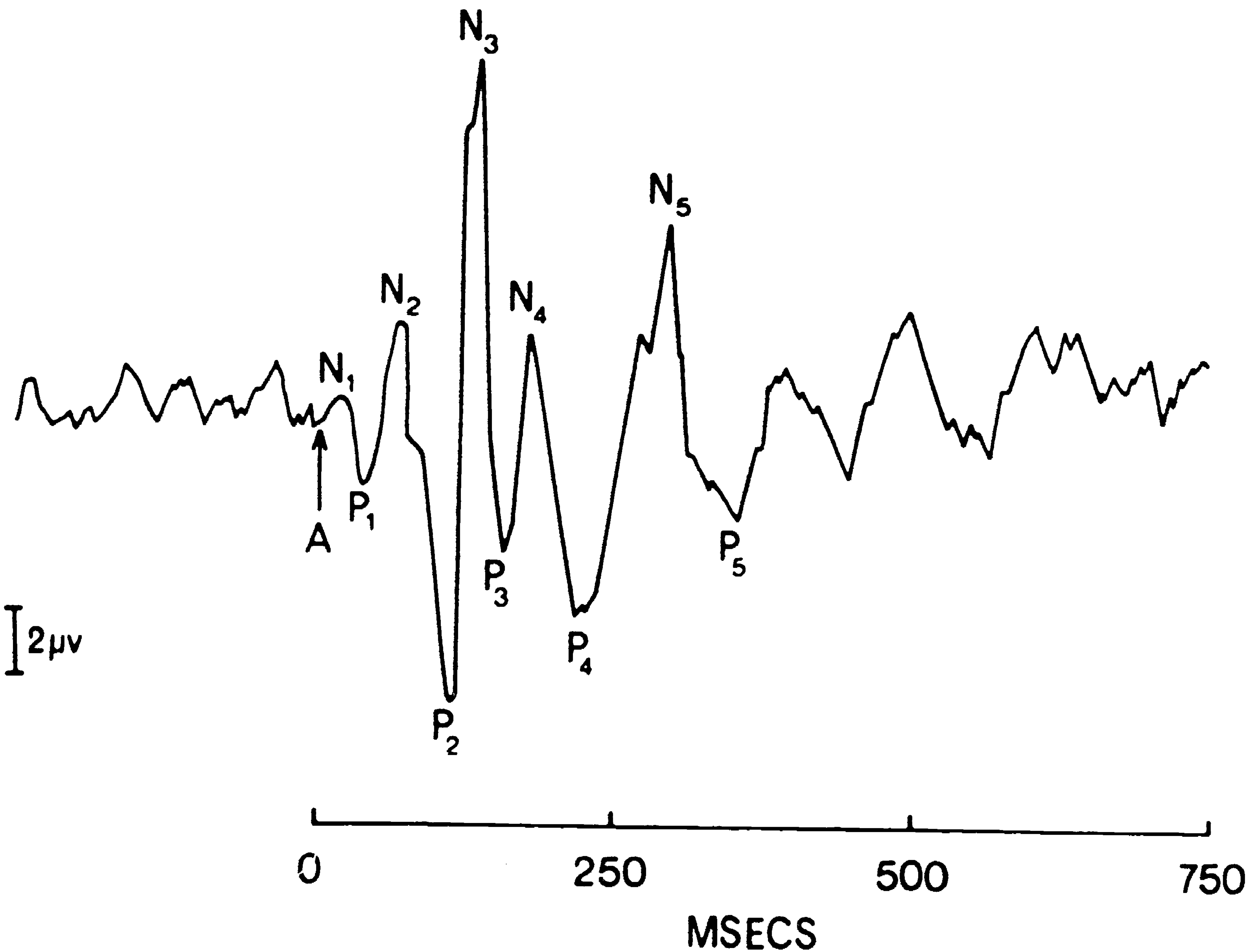
WAIS Test	Variance	Complexity	Complexity Minus Variance
Information	-.64	.55	.68
Comprehension	-.50	.53	.59
Arithmetic	-.57	.56	.65
Similarities	-.69	.54	.71
Digit Span	-.54	.49	.59
Vocabulary	-.57	.62	.68
Verbal Total	-.69	.68	.78
Digit Symbol	-.28	.32	.35
Picture Completion	-.47	.52	.57
Block Design	-.50	.45	.54
Picture Arrangement	-.36	.45	.46
Object Assembly	-.32	.45	.44
Performance Total	-.53	.53	.60
WAIS Total	-.72	.72	.83

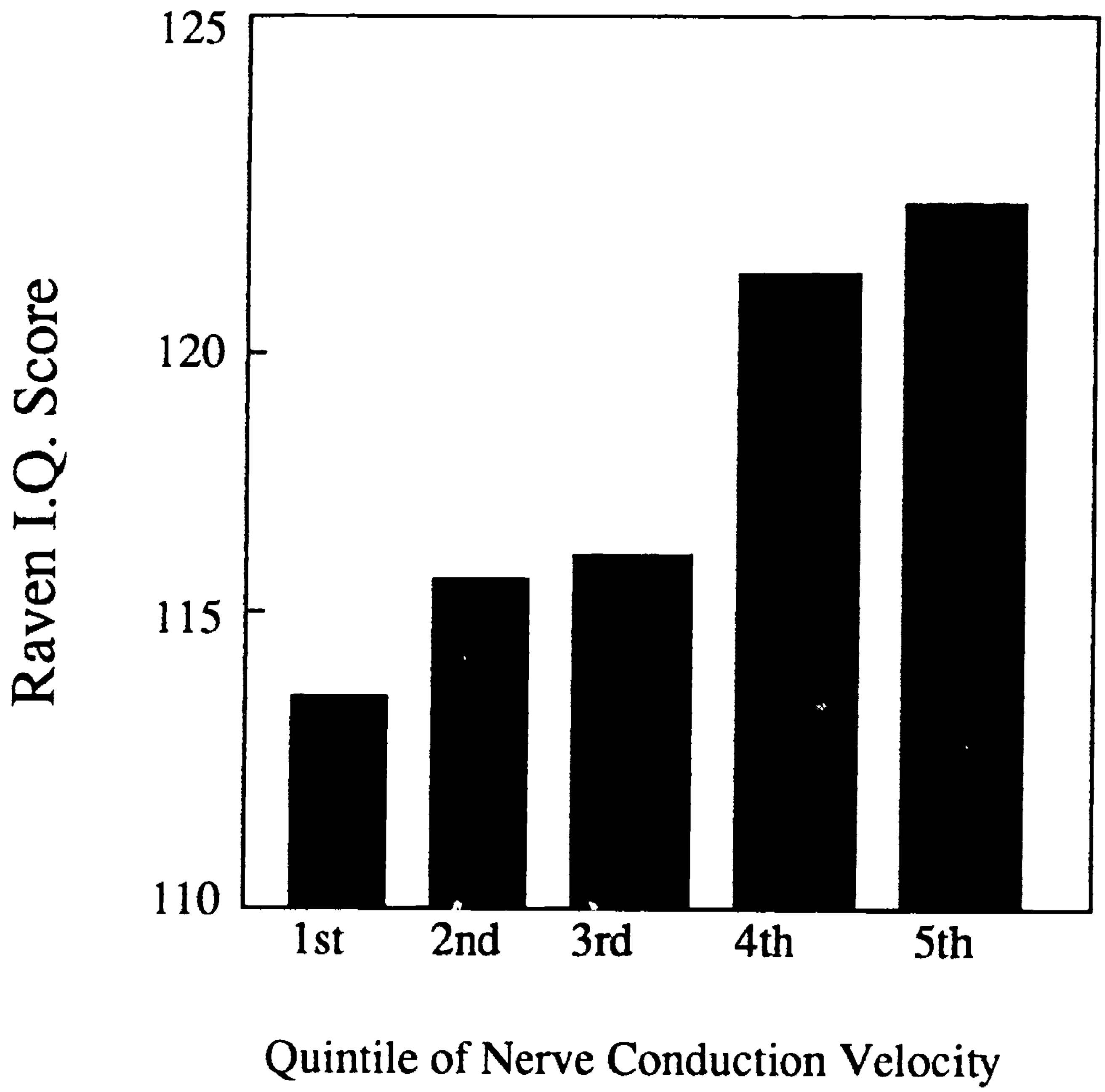
1
Adapted from D.E. Hendrickson (1982, p. 205). The biological basis of intelligence. In H.J. Eysenck (Ed.). A model for intelligence. New York: Springer Verlag.

Figure Captions

Figure 1. Diagrammatic representation of the average evoked potential, following signal at point A. (adapted from Hendrickson, 1982, p. 191).

Figure 2. Mean Raven IQ score of five groups of college students showing progressively more efficient nerve conduction velocities (from slow [1] to fast [5])
in the visual tract (adapted from Jensen, 1991 and Reed & Jensen, in press).


N_3
N_5
N_2
N_4
N_1
P_1
A
P_3
P_5
P_4
P_2
2μv
0
250
500
750
MSECS


125
120
115
110
Raven I.Q. Score
1st
2nd
3rd
4th
5th
Quintile of Nerve Conduction Velocity