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INDIVIDUAL DIFFERENCES IN COGNITIVE ABILITIES[1]

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INTRODUCTION

Traditional topics and issues of differential psychology continue to receive attention in contemporary research These topics include the identification and measurement of dimensions of IDs[2], models of structural relations among these dimensions, the origin, growth, and possible decline of differences in intellectual ability as a function of (*a*) genetic and maturational factors and (*b*) environmental factors describable in terms of opportunities for learning, practice, and transfer, and the applications of differential psychology to problems of assessment, selection, guidance, education, and training of individuals

A discernible new trend, however, is a budding but fitful and hesitant courtship between two traditionally separate disciplines of psychology—psychometrics, on the one hand, and experimental cognitive psychology, on the other Not clear yet is whether this courtship will eventually lead to anything like a marriage or other basis for cohabitation, but a growing body of literature addresses IDs in cognitive processes identified through experimental investigations, usually carried out in laboratory settings, of performance in various "cognitive" tasks such as comparison of stimuli, "mental rotation" of spatial representations, recognition and recall of series of verbal or figural stimuli, and comprehension of linguistic strings—in short, tasks that in many ways resemble, or are even identical with, those found in conventional tests of aptitudes and abilities (20) Some of this literature purports to be oriented toward the better understanding of the nature of these aptitudes and abilities (77), but some of it is directed toward the use of ID findings in the refinement of psychological theory (42) In either case,

[2]Abbreviations for terms and phrases frequently used in this article are as follows ETS, Educational Testing Service (Princeton, NJ), FA, factor analysis, factor-analytic, GRE, Graduate Record Examination, ID, individual difference(s), IQ, intelligence quotient, PA, paired-associates, PMA, Primary Mental Abilities (test); RT, reaction time; SAT, SAT-V, Scholastic Aptitude Test (-Verbal), SES, socioeconomic status, SI, structure of intellect, WAIS, Wechsler Adult Intelligence Scale, WISC, Wechsler Intelligence Scale for Children

it reflects attempts to identify fundamental processes in perception, learning, memory, problem solving, and other mental activities through study of IDs in task performances Performances either in psychological tests or in laboratory experiments are seen as exemplifying information processing events or sequences thereof; IDs are regarded as residing, at least in part, in the parameters of these events that can be measured or estimated through observations of reaction times, error rates, and other indicants

In historical perspective, this current trend represents a coming to full circle of tendencies that were evident already around the turn of the century when J McK Cattell, Binet, Spearman, and others attempted, with little real success, to measure intelligence through observations of simple processes such as sensory discrimination, choice reaction time, and memory span What is new is a more precise technology of experimentation and a greatly elaborated approach to the study of mental processes, represented for example in the information processing theories described by Simon in the present volume (see pp 363–96) The question to be addressed is whether current efforts have any greater promise of success

We limit this review to consideration of contemporary research and theory in individual (and group) differences in cognitive abilities and performances, including both the work with a primarily psychometric orientation and work being conducted in experimental cognitive psychology Personality variables are treated only to the extent that they are regarded as indicants of cognitive processes, styles, and strategies of performance

Partly in response to the intense public concern of recent years about the claimed high heritability of intelligence, the possible involvement of genetic factors in black-white differences in mean IQ, and the decline of scholastic aptitude and achievement among various groups over the past decade (185), there appeared numerous materials addressed to the nature of intelligence, abilities, aptitudes, and achievements Resnick's (133) collection of conference papers emphasized the above-mentioned possibilities of combining psychometric and experimental approaches in the study of intelligence, but ethological and cultural aspects were also treated Another set of conference proceedings (57) revealed a continued division of opinion among psychologists as to whether aptitude and achievement variables are distinguishable either theoretically or empirically In our view, they are, at least in many contexts Buros (15) brought out a collection of reviews of standardized ability tests and recounted his 50 years of experience in editing test reviews (16) Relevant textbooks included those of Brody & Brody (13) and Buss & Poley (19), the former addressed to the meaning of results from group and individual general intelligence tests, the latter focusing on FA studies of cognitive abilities as well as personality and affective variables Useful theoretical and historical articles are available (17, 176)

Literature addressed to the general public or to school people included a generally accurate and comprehensive survey of intelligence testing by Fincher (46), a polemic against IQ tests by Fine (47), and a collection of papers generally unfavorable to the use of aptitude tests in schools (71) Psychologists have shown little initiative in providing persuasive answers to the polemic writings

TRAITS, PROCESSES, AND COMPETENCE PHENOMENA IN COGNITIVE PSYCHOLOGY

Because developments in experimental cognitive psychology and in information processing and similar theories are treated in numerous chapters in this and previous volumes of the *Annual Review of Psychology,* our discussion of relations between cognitive theory and differential psychology can be brief We must start, however, from the traditional notions of trait, ability, and aptitude that still underlie much work in psychometrics It is frequently claimed that concepts like intelligence, "*g*", ability factor and the like are statistical abstractions or even artifacts arising from psychometric operations Some of these concepts may indeed be such artifacts, to a degree, "intelligence" is one such artifact, to the extent that it is measured essentially as a weighted average or composite of a number of more basic traits But it is not wholly an artifact, it has reality as an underlying dimension that appears in numerous kinds of cognitive tasks According to at least one type of factor model—the hierarchical model espoused by a number of authorities (24, 69)—factors have different levels of generality, "*g*" being the most general, with *Gf* (fluid intelligence), *Gc* (crystallized intelligence), and possibly *Gv* (visual intelligence) factors having only slightly less generality At even lower levels of generality, numerous "primary" factors of mental ability have been identified (40) Series of well-designed FA studies have produced solid and generally replicable information on major dimensions of human cognitive ability at various levels of generality, although there is undoubtedly much more to be learned about these dimensions Interpretations of factors in terms of relative magnitudes of factor loadings and corresponding intuitions or observations concerning the involvement of different kinds of knowledge, skill, and psychological processes have led to generally satisfactory descriptions of the underlying traits The theory of multi-item tests has achieved much of its success by assuming the operation of "latent traits" in accounting for item and function operating characteristic curves, although test theory has not fully exploited a multifactorial view of item performance, nor have FA studies taken full advantage of test construction procedures suggested by test theory (22, 106)

Studies of cognitive tests in psychometrics have always been inspired at least in part by a process view of mental activity, indeed, Galton, Binet, Spearman, and Thurstone can be regarded as having been among the first cognitive psychologists There is nothing in the theory of FA that requires that the variables be scores from paper-and-pencil psychometric tests, the variables can equally well be observations (RTs, slope parameters, etc) arising in the study of laboratory tasks Recent use of FA and other correlational methodologies by the current generation of cognitive psychologists (80, 136) is actually a continuation of a tradition previously established The use of procedures in which variations in task variables are introduced to generate possible variations in the extent to which a particular ID dimension is revealed in different observed variables represents no real departure Recent work has not always attended sufficiently to such problems as sample size, avoidance of experimental dependence, and procedures of factor extraction and rotation (21), with the result that some of the results are open to question Nevertheless, studies employing the new laboratory paradigms have begun to identify several ID dimensions that are not entirely specific to particular cognitive tasks and that show interesting connections with test performances (see below)

Whether ID dimensions are revealed by FA or by several new techniques such as what Sternberg (153) calls componential analysis, the psychological status of such dimensions poses questions Are these dimensions necessarily linked to actual psychological processes or mental operations? Or do they represent IDs in the contents or capacities of "sensory buffers," "memory stores," or other postulated aspects of "mental architecture"? If they correspond to processes, are these processes of a fundamental and pervasive character, i e critical to task performance and generalizable over many types of tasks, or do they reflect particular strategies of task performance that happen to be selected by individual subjects, who can readily use other strategies under appropriate cues? If they represent differences in characteristics of sensory buffers or of memory stores, what does this imply for the nature and organization of the sensorium or of memory?

Further, what is the significance of IDs manifested at a particular point of time in a particular group? Are they reliable and consistent over time? If so, what is the course of their development over the life span? To what extent are they subject to change through maturation, learning, short-term physiological influences, etc?

The posing of such questions may imply particular theories and views of behavior and performance, possibly other kinds of questions would be suggested by theories of behavior that do not depend on information processing views In any event, there is as yet only very limited information

available for answering these questions. Possibly the major virtue in cognitive psychologists' renewed attention to IDs in performance is that it will prompt increased efforts to provide theory and data adequate for answering such questions Differential psychology may therefore hold promise for encouraging the development of basic psychological theory, with an incidental payoff in the form of better ways of specifying the construct validity of ID dimensions Notions of trait, ability, and aptitude possibly can be replaced by concepts with a closer nexus with psychological theory

STUDIES OF BROAD ABILITY DOMAINS

Should we speak of cognitive *ability,* or should we speak of cognitive *abilities?* A persistent tension has existed between those who believe that human cognitive capacities can be well summarized in a single global concept of intelligence and those who prefer to emphasize the multidimensional character of the concept The bulk of recent research is predicated on a multifactorial view, yet, in the course of providing a 70-year history of the Binet intelligence test, Thorndike (161) questioned the tendency to "fractionate" abilities He pointed out that as much as 80% of the test variance can be explained by the first principal factor and that the overall IQ score is very stable over time whereas patterns of abilities may be unstable The issues raised here are complex, but we would point out that even the facts cited by Thorndike are not inconsistent with a multifactorial model that provides for a strong general factor along with group and narrower factors that are differentially subject to genetic and environmental effects

Standardized Intelligence Tests

Although the period under review apparently produced no new FA studies of the Stanford-Binet intelligence test, the factor composition of several other widely used intelligence tests was often investigated Studies (149, 184) continued to confirm at least two reliable and interpretable dimensions (verbal and performance) in the WISC and the WAIS, Conger & Conger (28) claimed as many as four or five reliable dimensions in the WISC

Raven's Progressive Matrices test (in either black-and-white or colored versions) generally has been considered an excellent test of the *g* factor of intelligence Wiedl & Carlson (183), however, factor-analyzed data from 35 items of the test given to 180 primary-grade children, finding three factors Concrete and Abstract Reasoning, Continuous and Discrete Pattern Completion, and Pattern Completion Through Closure Their results implied that the task structure is less differentiated than Raven had suggested, since there was no distinction either between concrete and abstract reasoning items or between continuous and discrete pattern completion Results must

be viewed as tentative, however, because the factors may to some extent be artifacts of item difficulties and age differences Thissen (158) demonstrated the utility of a multiple category latent trait model for obtaining information about an examinee's overall ability on the Raven test by inspecting specific incorrect responses For the lower half of the ability range, this approach yielded up to twice as much information as a traditional binary model The results of these studies might profitably be looked at from the perspective of the information processing model proposed by Hunt (76), who considered what sort of computer program could solve problems presented in Raven's test Analysis disclosed that a score within the normal adult range on the test could be obtained through the application of either a Gestalt algorithm based on manipulating visual images or a reduced analytic algorithm based on applying formal operations Hunt noted that a useful diagnostic test or scoring method would differentiate between these two styles of problem solving The failure of the Raven test to do so thus casts doubt on its use as a measure of general intelligence Lunneborg (108) found that a battery of information processing task measures could predict only 11% of the variance in Raven test scores, as compared to as much as 36% for vocabulary and the performance scale of the WAIS Explanations for the relative independence of the information processing tasks and the Raven task remain unclear but deserve further study

Factor-Analytic Studies of Broad Ability Domains

In recent years there have been few studies that attempted to span a wide range of abilities in a single battery subjected to FA One investigation of this type, of special interest because it involved brain-damaged patients, is that of Royce et al (138), who administered a battery of 49 measures from 22 brain-damage tests A FA yielded 6 perceptual factors, 4 conceptual factors, and 3 uninterpretable factors Correlations of factor scores with presence of damage in 12 neurological categories revealed that about half of the interpretable factors were relatively localized, the remainder being relatively diffuse Verbal ability was localized in the left hemisphere and spatial orientation in the right hemisphere, in agreement with previous research In a few cases brain damage was associated with good performance on a factor, a finding that these authors thought might suggest the operation of compensatory functioning

Multifactorial Test Batteries

A revised version of the well-known ETS Kit of factor reference tests was published (62), primarily to provide better marker tests of 23 distinct factors in research Oriented toward practical applications in selection and guidance, the Comprehensive Ability Battery (59) offered tests of 20 separate

primary factors, along with suggestions concerning scoring to produce measures of group factors There is marked overlap between these two batteries, both in the factors covered and the types of tests used to identify the factors Cory (30) developed a computerized battery of tests called the Graphic Information Processing (GRIP) battery The advantage claimed for this battery is not its potential for adaptive testing, a feature that is not utilized, but the possibly greater verisimilitude of its tasks to real-life tasks, stimuli and test formats are presented at a cathode-ray display terminal For example, a moving stimulus can be presented, item exposure time can be controlled, measures of tracking performance can be obtained, and response latencies can be recorded FA and validity studies were claimed to show that the GRIP battery provides valuable information on abilities that is not contained in the operational paper-and-pencil battery used by the Navy for selection and placement This computerized test battery thus appears to represent a promising development that should be replicated in nonmilitary settings

Factor Models of Cognitive Abilities

Both Cattell's theory of fluid and crystallized intelligence factors and Guilford's Structure of Intellect (SI) model inspired research during this period Undheim (166) determined that fluid and crystallized abilities are separable in children but are less differentiated than they are in adults Hundal & Horn (75) used Tucker's interbattery FA method to relate fluid and crystallized intelligence to performance on 10 learning tasks. Tasks were constructed so as to involve either paired-associates or serial learning, either meaningful or nonsense stimuli, and figural, semantic, or symbolic presentation Considerable independence between learning and intelligence was found, but the major common variance seemed to represent meaningful associations and learning by such associations, with intelligence involving primary memory to a lesser extent Fluid and crystallized intelligence were about equally involved in primary memory, but acquisition mediated by meaningful associations was more closely related to crystallized intelligence

Undheim & Horn (167) criticized the methodology underlying much of Guilford's FA research, arguing that the use of Procrustean rotations and the overextraction of factors may produce misleading results They emphasized that while Guilford's model has been useful for test construction purposes, there is no compelling support for the model as a description of human behavior In the context of the SI model, O'Sullivan & Guilford (124) examined social intelligence and obtained evidence for six behavioral cognition factors separate from previously recognized intellectual abilities, these results must be viewed with some caution in the light of Undheim & Horn's criticisms Favero et al (45) performed an extensive test of the SI

model, using one test for each of 76 cells in the model, along with verbal, nonverbal, and composite scores from the Lorge-Thorndike Intelligence Test Despite a sample size of 34, a FA was performed, the results of which are practically meaningless Other analyses, however, found that the median correlation between test dissimilar in all the dimensions of the model (operations, contents, products) was substantially greater than zero and did not differ appreciably from the median correlation between tasks similar on a dimension This finding questions not only the orthogonal structure of the model but also its validity as a model of behavior If the dimensions of the model have any meaning, it would be expected that tests similar along a dimension would be more highly correlated than dissimilar tests It is unfortunate that this study, involving an extensive test battery, used so few subjects This difficulty underscores Undheim and Horn's estimate that a test of the entire SI theory would require at least 96,000 subject hours

Learning-Ability Relationships

A perennial question has been whether any aspect of measured intelligence predicts ability to learn Hints of possible relationships were obtained in the study by Hundal & Horn (75) already mentioned Labouvie-Vief et al (97, 98) met with limited success in a series of experiments investigating the effect of instructional conditions on relations between Raven and digit-span scores and PA learning The only meaningful result found was that Raven test scores were a better predictor of PA learning when an imagery instruction was employed, while digit-span scores were more predictive when PA items were presented in a speeded condition These authors concluded that a major source of difficulty in research on learning-ability relationships is the factorial impurity of the ability measures A study by Hultsch et al (73) provides yet another possible explanation for the general failure of the studies by Labouvie-Vief et al to yield meaningful results. Instead of assuming that learning performance on a task is unidimensional, these authors used Tucker's method of analyzing learning curve data to discover separate components of ability in learning They found a number of significant learning-ability relations that varied with age and stage of learning, but their study was only partially successful Relationships between learning performance and ability factors have thus continued to elude meaningful experimental analysis, the studies discussed here illustrate the need to consider both learning performance and ability measures as complex composites of pure components in order to establish interpretable relationships

Individual Differences Studied in Experimental Cognitive Psychology

In 1973, noting that "modern studies of cognition from an information processing point of view have revealed the existence of a very wide range

of individual differences," Hunt, Frost & Lunneborg (79) courageously initiated a program of research designed to develop "theoretically based intelligence tests" Though using relatively small Ns, their pilot studies suggested that parameters of various cognitive tasks had significant relationships with performance on scholastic aptitude tests measuring verbal and quantitative aptitudes Among the cognitive tasks used were the Atkinson-Shiffrin continuous PA task, the Sternberg STM-search paradigm, the Posner paradigm in which the subject compares alphabet characters either for physical or for name identity, and the Wickens paradigm of release from proactive inhibition in a free-recall task Later studies (80, 107) tended to confirm the original findings and identified still other relations, using both high-low verbal group comparisons and FA One of the best confirmed findings is a correlation of about –0 3 between an NI-PI score and verbal ability, the NI-PI score being the increment of mean RT in the Posner task under name-identity instructions over that under physical-identity instructions, this finding has been extended in interesting ways by other investigators (53, 94) Hunt (78) suggests that the magnitude of the relation may be even higher if a sufficiently wide range of ability is considered; he also shows that RT in comprehending negation in the Clark & Chase sentence-picture comparison task is substantially related to verbal ability only when the subject uses a particular strategy in performing the task Since the appearance of the report by Hunt et al (79), a number of investigators have pursued the possibilities it suggests. Chiang & Atkinson (26) confirmed relations between test scores and the slope parameters of the Sternberg task only when data were analyzed separately by sex, they also established satisfactory day-to-day reliability of these parameters Snow et al (150) continued to work with these data, introducing further tests and experimental variables, but with somewhat puzzling results. Yen (189) succeeded in finding substantial relations between parameters in two learning tasks and school aptitude and achievement measures in children from fifth to tenth grades Hogaboam & Pellegrino (65), however, failed to find significant relations between SAT and processing speeds in a semantic judgment task, as Hunt et al's findings might suggest. They propose that Hunt et al's results with the NI-PI variable reflect simply flexibility in meeting the rather unusual requirements of the name-matching task in the Posner paradigm Nevertheless, these authors' semantic judgment task is not highly similar to the Posner task

In commenting generally on these highly interesting and provocative endeavors, we would point out that it may be a mistake to use SAT-type measures as indicants of intelligence, such measures being loaded with educational and experiential effects Some investigators (88, 108, 150) have turned to the use of cognitive ability measures that may be less affected by education, such as Raven's Progressive Matrices test or certain tests from

the ETS Kit of Factor Reference Tests On the other hand, it can be argued that finding information-processing correlates of SAT-type measures could help explain why individuals profit differentially from the learning experiences that to a degree are common to all

Two other promising theory-based efforts to connect cognitive processing parameters with psychometric variables are those of a group in Canada (90) and the work of Bachelder & Denny (5) in proposing a theory of intelligence based on the complexity or difficulty aspects of memory span performances In the former case, the investigators reinterpret performances on several types of intelligence and learning tasks in terms of Luria's theory of simultaneous vs successive scanning, but in view of the limited test battery they have assembled they will need to marshal more varied evidence to support their interpretations Bachelder and Denny offer evidence that many types of conventional intelligence test formats (e g arithmetic reasoning tasks involving comprehension of long sentences with numerical details) contain unrecognized span memory components

ABILITIES IN PARTICULAR DOMAINS

Psychometric studies have identified a substantial number of primary abilities in verbal, fluency, creativity, reasoning, number manipulation, perceptual, spatial, memory, and other domains of cognitive activity Although the domains themselves are reasonably distinct, in the sense that abilities in different domains are relatively independent, the delineation of separate abilities within domains is generally unclear This is possibly because the tests used to measure the several abilities in a domain are not sufficiently refined to control the stimulus, process, and response variables that must be controlled to obtain pure ability measurements

It is not wholly accidental that the tasks that have been studied in recent years by experimental psychologists are frequently tasks that appear in tests of the various primary abilities. Experimental studies hold promise of elucidating the nature and developmental characteristics of these primary abilities, as well as permitting clearer differentiation of these abilities Here we review selected studies in several important domains Some studies are cited only because they draw attention to interesting and possibly novel dimensions of IDs, or explore relations of these dimensions to variables like age or social class Other studies explore covariations of experimental task performances with psychometric measures

Language Abilities and Skills

It might appear that Hunt (78), in discussing "the mechanics of verbal ability," demonstrates that information processing parameters in several

cognitive task performances are related to the well-known "verbal knowledge" factor (V) that is measured particularly well by wide-range vocabulary tests, but since Hunt's results pertain to fairly global measures of verbal aptitude, the relation may have more to do with a higher-order verbal intellectual ability such as *Gc* as identified by Horn (69) and others The exact nature of this relation deserves much further examination Platnick & Richards (129) found no significant relation between tachistoscopic word recognition thresholds and SAT-V scores when word familiarity is controlled

It may be suspected that many verbal intelligence tests are strongly affected by reading skill, but recent research emphasizes that reading skill is more complicated than it may appear to be Using a variety of oral reading tasks derived from an information processing analysis, Frederiksen (49) identified five components. grapheme encoding, encoding multiletter units (orthographic patterns with special sound-correspondence features), phonemic translation, automaticity of articulation, and depth of processing of lexical units In a relatively small sample ($N = 20$ high-school students), individual differences in these components accounted for most of the variance in standardized reading comprehension tests Studies by a group at the University of Pittsburgh (127, 128), who obtained results in general agreement with Frederiksen's, suggest that speed of word recognition varies widely among high-school students and is a major source of variance in discourse comprehension (by reading) far more important than any differences in strategies specific to understanding discourse as such Spearritt et al (151) concluded on the basis of an extensive FA study that literal and inferential reading skills are essentially the same The studies mentioned here would have been more informative if attention had at the same time been given to listening comprehension, i e basic knowledge of spoken language apart from reading skill

In an experimentally oriented study (6) there is a strong suggestion that in tasks involving reading, college-age subjects differ in the extent to which they use or are affected by knowledge of orthographic rules A priori considerations suggest that these differences might relate to the distinction between "language-bound" and "language-optional" subjects proposed by Day (34), revealed in dichotic-fusion experiments (33), but to our knowledge this possibility has not been investigated

There is renewed interest in dimensions of speech performance and their correlates in more general cognitive abilities Studies of children's speech behavior (63, 85) indicate that some aspects, such as syntactical elaboration, are correlated with IQ independent of social class variables, speech styles, however, are related to social class (86) In adults, mean duration of utterance and latency of response to an interviewer are related to verbal IQ (114) In a FA of 46 measures on misarticulating children, clinical judgments of

different aspects of speech performance (articulation, auditory processing, reading and spelling, etc) showed good correspondence with psychometric variables (84) One especially interesting aspect of speech performance is the ability to "shadow" speech at short time intervals, Marslen-Wilson (113) found that some individuals can shadow accurately at intervals as short as 0 25 sec To our knowledge, relations between shadowing ability and other cognitive processing variables have not been investigated from an ID standpoint

Creativity and Fluency of Ideation

The nature of creative thinking has been further explored in a number of books (156, 177) Stein (152) reviewed procedures for increasing creativity in group and individualized settings, see also experiments by Locurto & Walsh (104) and Meichenbaum (118)

MEASURES OF CREATIVE THINKING Ward (175) contrasted convergent and divergent measures of creative thinking by administering the Remote Associates Test (in both a recognition and a production format) and Uses and Pattern Meanings tests to children Convergent and divergent measures shared little variance not also shared with IQ and achievement, both of which tended to correlate more with convergent than with divergent thinking Gough (56) found that word associations of moderate but not extreme atypicality provided a better prediction of rated creativity than did very rare responses, which may be more indicative of some form of disturbance An alternate explanation is that the result arose from a statistical artifact, in that measures derived from very rare responses may have had much lower reliability Gough also obtained tentative support for a hypothesis that stimuli drawn from a specific domain provide better prediction of creative achievement in that domain than would a general word association task In an approach similar to Gough's, Frederiksen & Ward (50) developed a series of items utilizing complex life-like problems in psychology in order to assess creative potential among undergraduate psychology majors Following Flanagan's method of obtaining critical incidents in research activities, they composed four types of situational tests. formulating hypotheses, evaluating proposals, solving methodological problems, and measuring constructs Construct and criterion validity information was obtained from a large sample of persons taking the GRE Advanced Psychology test The newly developed Tests of Scientific Thinking (TST) were found not to overlap greatly with GRE scores Students scoring high on the TST tended to engage in more professional activities as first year graduate students, a pattern that was not found for the GRE, thus, the creative thinking tests may provide useful predictive information about graduate student performance

DIVERGENT THINKING AND COGNITIVE PROCESSES Sacks & Eysenck (139) related the convergent-divergent thinking distinction to the retention of abstract and concrete sentences Young adults were classified as convergers or divergers based on an intelligence test and five items of Uses of Objects presented without a time limit Subjects were then shown six abstract and six concrete sentences and immediately following were given a forced-choice recognition test to measure retention of the sentences. The effect of abstractness-concreteness was highly significant for convergers but not for divergers Convergers had more difficulty in recognizing abstract sentences These authors proposed that understanding of abstract sentences requires consideration of more interpretative possibilities than is required for concrete sentences, and that divergers are better than convergers at producing a variety of interpretations

Thinking, Reasoning, and Problem Solving

Measures of several rather poorly differentiated primary abilities in the reasoning domain are offered in the ETS Kit of factor tests (62) General Reasoning, Logical Reasoning, and Induction General Reasoning appears to have strong elements of mathematical aptitude. Logical Reasoning seems to represent what was previously called Deduction Strangely, no test involving analogy items was included in measures of these factors, possibly because tests of analogical reasoning may relate to a higher-order factor such as *Gf,* and because these tests frequently include an advanced vocabulary component

Experimental studies, at any rate, have begun to provide detailed analyses of processes in solving several types of reasoning tasks, including inductive, analogical, and deductive reasoning. The most ambitious program is that of Sternberg (153), whose "componential analysis" procedures have already been mentioned After reviewing earlier theories, Sternberg presents a theory with six information processing components of analogical reasoning that can be operationalized in various experimental settings. encoding, inference, mapping, application, justification, and (as a general control process) preparation-response Several models concerning the combined operation of these components are tested, some models being better supported by data than others It is concluded that whatever model is most correct, it is general over subjects, in that there is no evidence of consistent IDs in models used by different subjects. IDs are revealed in the extent to which individuals use any model at all, however, and in their strategies, differentiated by relative amounts of time devoted to the several components—particularly when the discovery of relevant attributes is critical to solution success Component scores from experimental tasks account for large proportions of variance in reference ability tests, especially in letter-

series, reasoning, and vocabulary tests The preparation-response parameter tends to make the strongest contribution in this Sternberg claims, with much justice, that his approach represents an information processing analysis of what is ordinarily meant by intelligence. A somewhat related approach, also concerned with analogical reasoning, is that of Whitely (180), but in this case it is addressed particularly to verbal analogy tests Components classified as short-term and long-term memory processes, control strategies, and response implementation were operationalized in ten tasks representing segments of analogy-item performance, a FA yielded three factors corresponding generally to the three hypothesized types of components All three factors contributed to the prediction of response time measurements on a complete verbal analogy test In a further study, Whitely (181) attempted to identify "semantic structures" that govern verbal analogy performance

At this point it is difficult to align the generally similar results of Sternberg's and Whitely's studies, but these approaches deserve further exploration Sternberg's analysis seems the more detailed and rigorous, but as Whitely notes, "individual differences in item-solving strategies and the content of memory stores" (180, p 476) need more attention Whitely & Dawis (182) have made some progress in exploring effects of cognitive intervention on analogy-item performance

Effects of cognitive intervention were of central interest in a study (67) of performance on letter-series completion tests, ordinarily regarded as measures of the Induction factor Following a model provided by a computer simulation, the investigators gave school children explicit training on two out of four hypothesized component processes, the detection of interletter relations, and the discovery of periodicity Both experimental and control groups made gains (varying somewhat with age); part of the gain could be attributed to practice, but the greater gains in the experimental group indicated that the hypothesized processes are trainable "Consequently," the authors remark, "this study supported the psychological reality of the identified processes and suggested the potential of instruction in these processes for improving intellectual competence" (67, p 356)

Possibilities of accounting for and modifying IDs in problem solving ability through cognitive processing analysis have been addressed in several books and monographs (1, 132, 141) Allwood (1) concludes that the analysis of these IDs must take account of the type of problem (a taxonomy is needed!), the individual's knowledge base, and the individual's characteristic solution strategies as they interact with problem type

The studies and reviews mentioned here have made no explicit attempt to explain or clarify the factorial structure of the abilities in the reasoning domain In fact, Sternberg's (153) work shows only small evidence of differ-

ent information processing components as predictors of scores on several psychometric tests that ordinarily have different loadings on verbal, inductive, and deductive factors It is apparent that much further theoretical and empirical work in coordinating experimental and psychometric findings will be needed

Abilities Concerned with Number and Quantity

The ETS Kit (62) offers tests of only one factor explicitly concerned with number and quantity, the Number factor, defined by tests of speed in simple arithmetic operations As mentioned earlier, however, the General Reasoning factor is defined by tests involving reasoning with quantitative concepts There appears to be little recent work in the experimental analysis of either of these factors One can continue to assume that the Number factor represents degree of practice and retention of basic arithmetic skills, still largely unknown is whether individuals differ in the extent to which they can develop these skills. Some of the work of Hunt et al (79) found relations between quantitative reasoning aptitude and certain information processing variables, but some of the tasks from which these variables are derived involve numerical operations, as in the Brown-Peterson paradigm where the interference phase of the task requires the subject to count backward by 3s Persons high on N or quantitative aptitude may incur less interference from this phase

Taylor et al (155) sought cognitive measures related to high school students' performance in algebra and geometry Contrary to what might be expected, verbally oriented tasks were more prognostic of success in geometry than they were in algebra Soviet studies in the mathematical abilities of children have become available through a translation (95) of a work by Krutetskii, who has even used FA, in addition to detailed observations and interviews of individual children solving mathematical problems, in shaping a theory of mathematical giftedness Some components that help determine giftedness, even though they are of a very general character and not specific to mathematical behavior, are the speed of mental processing, computational skills, good memory for symbols, numbers, and formulas, spatial ability, and the ability to visualize mathematical relationships and dependencies Krutetskii believes that giftedness in mathematics is furthered by what he calls "inborn inclinations "

Perceptual Skills and Processes in Vision and Audition

Several factors represented by tests in the ETS Kit (62) pertain to abilities in perceiving and manipulating visual forms Perceptual Speed, Spatial Orientation, Spatial Scanning, Visualization, Flexibility of Closure, and Speed of Closure Possibly Figural Flexibility and Figural Fluency should

also be mentioned in this group as involving the generation of visual forms The tests of visual perceptual skills included under this group of factors contain many tasks similar to those studied in experimental cognitive psychology We can discuss only a small sample of the relevant studies

As pointed out by Ekstrom (40), factor analysts have had continual difficulty in differentiating and interpreting Spatial Orientation and Spatial Visualization factors (131), both of these (as well as some other factors in this domain, such as Perceptual Speed) could be said to involve some kind of mental encoding and representation of spatial configurations along with "mental rotation," operations that have been studied experimentally (125, 146) Let us consider whether experimental studies of visual perceptual tasks might throw light on the structure of abilities in this domain Because of the paucity of available data, however, much of what we have to say is speculative

Cooper (29) studied IDs in performing a task in which subjects are first required to mentally rotate a visual shape to a specified position before comparing it as same or different to a probe stimulus that may exhibit any of several degrees of change or perturbation (over and above rotation) from the original Subjects differed in their mental rotation speeds (during the "preparation" phase), they differed also, somewhat independently of mental rotation speeds, in the manner and extent to which they were affected by the amount of perturbation in the probe stimulus Type I subjects were fast comparers, unaffected by perturbation, they appeared to make a holistic comparison of mental representation and the probe stimulus Type II subjects, more plentiful in the small sample tested, were generally slower than Type I subjects on "different" responses, and were much affected by amount of perturbation; they appeared to make analytic, point-by-point comparisons This difference between Type I and II subjects presents a rough parallel to the contrast between "structural" and "analytic" comparers reported by Hock & Marcus (64), but Cooper points to differences in procedures and results that make this parallelism somewhat suspect Unfortunately, neither Cooper nor Hock & Marcus administered any spatial ability tests whose correlational patterns with the experimental task parameters might have suggested something about the interpretation of factors underlying the tests At the same time, the finding of different types of subjects suggests that linear correlational analysis of the data would be problematical, except perhaps by analysis for separate groups Also, Cooper reported (unpublished information) that to some extent subjects may change strategies when the structure or demands of the task make it appropriate to do so

One of the few studies to investigate correlations between spatial ability test scores and parameters of experimental tasks in this domain is that by

Egan (39), who adapted Spatial Visualization and Spatial Orientation tests to a format that permitted taking latencies of correct responses. Egan found that number-correct scores on these tests were rather highly correlated, but that they each had negligible correlations with mean latencies of correct responses. He suggested that accuracy scores on Spatial Orientation tests represent "a form of concept verification in which examinees serially check the three spatial dimensions of a figure against their concept of what the figure should be." Visualization tests, on the other hand, "have properties analogous to physically turning an object in space, so that problems requiring a greater number of turns or turns of greater length required more time to solve" (39, p. 24) Putting these results together with the data from Cooper's experiments, we would suggest that the essential element in Spatial Visualization represents IDs in the speed of mental rotation in the preparation phase, while Spatial Orientation taps the ability of the subject to encode a visual form in order to compare it with another. In any case, Egan's results suggest that it is imperative to score spatial ability tests for power or accuracy separately from speed in making correct responses Further analysis would have to take into account the possibility that subjects can use either of two strategies in making visual comparisons It is conceivable that these different strategies are reflected in scores in Perceptual Speed tests such as Identical Figures, where figure comparisons are required

The suggestion that there may be IDs in skill in mental representation and manipulation of spatial forms raises the question of the possible relevance of imagery ability Ernest (41) identifies three approaches to the measurement of IDs in imagery. self-report questionnaires, spatial ability tests, and performance tasks Most of the research she reviews on correlates of imagery with learning, memory, perceptual processes, and conceptualization has used self-report questionnaires, but even self-reported imagery appears to be multidimensional Ernest postulates three dimensions. vividness, habitual use, and control, Cartwright et al (23) specify three dimensions relating to content figural, symbolic, and mimetic An elaborate but in some respects questionable FA by Richardson (134) supports relative independence among several dimensions of self-reported imagery, as well as relative independence of self-report dimensions and spatial ability test scores Nevertheless, Ernest believes that self-report and objective test score dimensions are not wholly independent If the spatial ability domain could be clarified along the lines suggested above, it might be possible to confirm certain relations with dimensions of imagery identified by self-report procedures

We briefly note several other intriguing studies in the visual perceptual domain Duda (38) used an analysis of IDs in the power-law exponents of

several subjective magnitude estimation tasks to establish a theoretical interpretation of Stevens's empirical findings in psychophysical judgment Forsyth & Huber (48) used an ID approach to study stimulus factors in the perception of ambiguous figures as either human or nonhuman Taylor (157) followed up an early study by Thurstone to identify ID dimensions of susceptibility to visual illusions

Extensive FA work in auditory abilities is currently being completed (J L Horn, personal communication) but has not been published in time for this review

Memory Skills and Capacities

Theories of cognitive processing assume that memory, in the sense of the acquisition, storage, and retrieval of information, is implicated in practically all performances that could be called cognitive Eysenck (43) reviews current theory and research on memory, with special attention to relating this work to IDs in intellectual, personality, motivational, and affective variables He stresses the importance of a process-oriented approach as opposed to a "boxology" that assumes memory storages of different "terms" (short, long, etc) Some of Eysenck's review overlaps considerably with the present review, in fact, except that he pays less attention to FA findings

However memory is regarded, memory of one kind or another is involved in all the domains and factors of IDs being considered here For example, the verbal knowledge factor refers to the richness and variety of the individual's memories for words and other linguistic entities, spatial abilities may involve the clarity and persistence of short-term memories for spatial forms But in FA work, the memory domain has been implicitly defined in terms of abilities that appear to control the individual's success in certain one-time learning tasks such as PA learning and memory span The latest edition of the ETS Kit (62) offers tests of three factors in this domain Associative Memory, Memory Span, and Visual Memory, the last of these being a new addition as compared to earlier editions. Ekstrom (40) reviews the empirical support for differentiating these factors

In an effort to get an interpretation of memory processes that would depend on various assumed attributes of memory contents such as imagery, acoustic, temporal, and affective, Underwood et al (165) performed a FA of 22 variables derived from episodic memory tasks that included standard paradigms in verbal learning research such as PAs, free recall, serial learning, verbal discrimination, and memory span "Semantic memory" variables such as SAT, vocabulary, and spelling were not included in the factor analysis because they showed no strong or interesting relationships with the episodic memory variables Five rotated orthogonal factors resulted, all

more or less task-specific, roughly they may be identified as Paired-Associate and Serial Learning, Free Recall, Memory Span, Recognition Memory, and Verbal Discrimination A tentative reanalysis (21) suggests that the first two of these are substantially correlated to form an Associative Memory factor at the second order These authors failed to find evidence of IDs in the use of memory attributes, explaining this failing as due to the "swamping" of the data by an associative learning factor and to the possibility that subjects are highly flexible in using whatever memory attributes are appropriate in a given task Thus, although the study confirms and expands previous knowledge about dimensions of memory ability, we come away from it with the feeling that it contributes little to their theoretical explanation Memory abilities simply exist, they can have considerable generalizability over tasks and conditions (126), but they defy psychological analysis Even Hundal & Horn's (75) finding of connections between primary and secondary memories and *Gf* and *Gc* abilities, respectively, does little to advance deep understanding of memory abilities

Jensen's assumption of a distinction between "associative (Level I)" and "conceptual (Level II)" abilities has continued to be questioned by investigators (99, 162) who point out that associative and rote memory tasks can engage higher-order conceptual operations They find that all types of school success are better predicted by conceptual ability than by associative ability

As noted above, Bachelder & Denny (5) propose that a general theory of intelligence can be erected on the basis of memory span phenomena But memory span ability has eluded theoretical analysis as much as associative memory ability Although it had been suggested (42) that memory span tasks tap individuals' use of mnemonic strategies such as rehearsal, grouping, and chunking, Lyon (109) obtained results that virtually rule out such possibilities Cohen & Sandberg's (27) data suggest that the connection between IQ and memory span centers in the individual's ability to retain the terminal items of a presented string, but it is not clear from this study what kind of memory store or process is involved Although they do not note the fact, their results also suggest that there may be other sources of ID variance in memory span performance Chi (25) suggests that memory span deficits in children may be due to failure to encode the stimuli rapidly and completely

Cognitive Speed

Cognitive Speed is hardly a distinct domain of abilities, many factors in domains discussed above are characterized by speed elements or contain them to the extent that the tests used to measure them are speeded or administered under a time limit But perhaps Cognitive Speed *ought* to be considered a separate domain, constituted by reclassifying the speed ele-

ments from other domains into this domain This might be especially desirable in view of the fact that many of the parameters of laboratory tasks refer to rate or speed of performance It has been noted above that Egan (39) recommended that spatial ability tests should be scored separately for speed and accuracy The generalizability of a speed element in spatial ability tests to speed elements drawn from other domains is unknown, although earlier studies (e g 105) have identified one or more general speed factors Although cognizant of the problem, Lunneborg (107) might have been more successful in relating reaction time measurements to psychometric variables if his procedures had taken more account of the speed aspects of the latter It would seem that a desirable strategy in studying relations between laboratory and psychometric tasks would be to insure that speed and accuracy components of performance in each case are separately considered Such a strategy has seldom been employed in the history of ID research, see also White (179) on this matter

COGNITION AND PERSONALITY

Factor analysis continues to be a useful tool in the investigation of personality-ability relationships Messick & French (119) found speed and flexibility of closure factors related to personality variables. Hakstian & Cattell (60) used both Tucker's interbattery FA and canonical correlations to examine relationships between 20 ability variables and 14 personality variables separately for males and females Relationships between the two domains were tenuous, especially in the case of females It was suggested that males and females may differ in the extent to which personality and ability measures are related

Schwartz (145) sought to explain previous findings that arousal during acquisition affects memory sometimes positively and other times negatively He hypothesized that arousal focuses memory on physical rather than semantic cues, and that its facilitative effect thus depends on the nature of the material to be learned Results supportive of this hypothesis were obtained for PA learning and clustering in free recall, but the data also permit other explanations

Turner & Horn (164) used a double cross-validation procedure to examine relationships between the 16 PF (Personality Factors) test and three factors identified in the WAIS Significant verbal ability-personality relationships were maintained under cross-validation, but there were no such relationships for memory and numerical abilities and only mixed findings for spatial ability Their methodology emphasizes the need to control for testing the significance of the numerous correlation coefficients in such studies to insure that obtained relationships are not simply spurious results due to Type I errors

Field Dependence-Independence

The field dependence-independence distinction, regarded as related to both cognition and personality, continued to provoke research during this period, as indicated by an extensive bibliography (186) Witkin et al (188) and Goodenough (54) reviewed implications of field dependence for education and also its relations with learning and memory Field-dependent and field-independent persons are said to be about equal in learning and memory abilities but different in the strategies they are likely to employ and in the types of material they learn easily Field-independents tend to make greater use of mediators, field-dependents often either cannot or do not impose structure on material, and thus need an external source of structure

Writing on the development of field dependence at both the individual and the cultural level, Goodenough & Witkin (55) state that the ontogenetic trend into the midteens is from dependence to independence, but the historical trend in the culture has been in the other direction Biological, environmental, and cultural factors are invoked to explain these trends A major restatement of the field dependence theory has also been presented by these authors (187) It now seems that there is no general restructuring ability or style across all domains, because FA studies have revealed that restructuring tendencies in visual and auditory modalities are separable, and such tendencies are related very little if at all across visual and verbal modalities Further, it is now thought that some individuals are "fixed" in their style while other persons are "mobile," i e by adapting their style to a particular situation they can be field-independent and exhibit high interpersonal competence This reconceptualization would seem to represent a departure from the original value-free notion of the construct, in that now it seems that persons can be classified along a dimension of interpersonal competence as well as along a second (perhaps correlated) dimension of cognitive restructuring, neither of which is value-free

CHANGES IN ABILITIES OVER THE LIFE SPAN

Recent years have seen increasing emphasis on abilities both in the very young and in the aged This research has proved useful in broadening our understanding of the nature of abilities, especially of how abilities change with age

Abilities in Infants and Young Children

The development and measurement of cognition and cognitive abilities in young children has received much attention in books (14, 91, 93, 101, 168) Two noteworthy studies investigated infants' cognitive performance, with emphasis on examining the validity of different measures of intelligence. Lewis & Gallas (102) related scores on the Mental Development Index of

the Bayley Scales of Infant Development, the Corman-Escalona Scales of Object Permanence, and measures of habituation and recovery on an attention task for 12-week-old infants The study is distinctive for its sample size ($N = 189$) and the narrow age range of the children The highest correlation obtained between any two performance measures was 0 22, suggesting that a developmentally constant, general intelligence factor does not exist in infancy Miller et al (120), however, found that measures of first fixation habituation ratio obtained from infants between 2 and 4 months old were predictive of performance at age 15 months on scales developed by Užgiris & Hunt (168) It thus appears that although habituation measures do not correlate highly with standardized measures of intelligence in the infant, they may nevertheless possess short-term predictive validity for later cognitive performance

The Piagetian approach to assessing the development of intelligence in young children has only rather recently been related to psychometric research in IDs in abilities of young children This research has largely involved correlating performance on Piagetian tasks with performance on psychometric tests For example, Neimark (122) established a connection between performance on the Embedded Figures Test and development from concrete to formal operational thought in a longitudinal study of several cohorts of children, but it is unclear whether cognitive style per se is important or whether general intelligence is actually responsible for the relationship Kuhn (96) found that the WISC correlated more highly with Piagetian task performance for children in grades 1–3 than for children in grades 5–7 Kuhn's explanation for this was that a child's general experiences affect performance on Piagetian tasks, whereas specific experiences affect performance on traditional IQ tests. However, other explanations are certainly possible, and indeed the finding itself needs to be replicated with different Piagetian tasks and with one group of same-age young children and another group of same-age older children. Hruza et al (72) concluded from a FA of adult data that Piagetian factors are independent of psychometric factors Examination of their factor matrix, however, suggests that an oblique structure would disclose a substantial relationship between the two types of factors Siegler (147, 148) has used a rule assessment methodology in an effective way to discover how children attempt to solve certain Piagetian tasks Although the focus of this research is on age differences, its methodology would seem useful in investigating individual differences as well

Abilities in Older Children

Research with older children has been concerned with stability of test scores, relationships between development of different abilities and relationships between age, test scores, and cognitive task performance Hopkins &

Bracht (68) noted that most previous research on test score stability has concerned individual rather than group IQ tests Children were administered the California Test of Mental Maturity in grades 1 and 2 and the Lorge-Thorndike Intelligence Test in grades 4, 7, 9, and 11 For verbal IQ, correlations involving measurements at grade 1 or 2 tended to be in the range 0 4 to 0 5, whereas from grade 4 onward, correlations were 0 75 to 0 85 Similar findings occurred for nonverbal IQ, except that stability first became evident at grade 7 rather than at grade 4, and the correlations were overall substantially lower than they were for verbal IQ

Atkin et al (4) used a multivariate modification of the cross-lagged technique to examine developmental relationships from grade 5 to 11 on 16 cognitive tests Separate analyses by race and sex revealed that the fifth grade measure of Listening, an aural comprehension test, consistently predicted a composite score from all tests in the eleventh grade better than the composite predicted Listening No other measure exhibited such cross-lagged differences, a finding that implied that Listening taps sources of later intellectual development more directly than any of the other tests, perhaps because only the Listening test is presented orally and involves no repetition of stimuli, so that it more than any other test demands attention, crucial to development We suggest an alternative explanation, namely that Listening measures rate of basic language development better than the other tests used, which are affected by extraneous sources of variance due to early differences in the acquisition of reading skills Atkin et al (3) also examined the differentiation hypothesis using these same data Several methods of analysis all suggested a small, gradual increase in the number of common factors, especially for the white groups Interpretation of any race differences must be very tentative because of small sample sizes for the black groups Olsson & Bergman (123) used a confirmatory FA model to investigate differentiation in a sample of Swedish children tested at ages 10 and 13 Differentiation occurred in the sense that factors were more separable at age 13, but integration occurred in the sense that unique variances were smaller at the upper age This finding emphasizes the need to consider not only the particular tests employed and the ages of the subjects but also the definition of differentiation

The important and pioneering work of Keating & Bobbitt (88), briefly noted above, extends the research methods of Hunt et al (80) into the period of childhood The basic design included three age levels (grades 3, 7, and 11), two ability levels (classified according to performance on Raven's Progressive Matrices test) and sex of subject Effects of these factors were examined for variables derived from three cognitive tasks the Posner letter comparison task, choice reaction time, and the Sternberg memory scanning task Age and ability main effects were generally significant, but there were

no significant sex effects or interactions Based on a stage analysis of the tasks, results showed that tasks or differences between tasks that had steps in common tended to yield correlations higher that those from tasks with no steps in common These results supported the validity of the stage analysis and furnished evidence for consistent IDs in the components

Aging and the Question of Declines in Abilities

The long-standing controversy as to whether any mental abilities decline with age has continued to be debated Botwinick (10) concludes that both cross-sectional and longitudinal studies show that some declines definitely occur, but that they may begin later in life, may be smaller in magnitude, and may include fewer abilities than previously thought Horn & Donaldson (70) engaged in a series of spirited debates with Schaie & Baltes (142) These debaters seem to have arrived at a substantial consensus regarding the facts, but their interpretations of the facts and their implications still diverge widely Horn & Donaldson insisted that the important finding is that aging decline in average intellectual performance is not mythical, there is decline for at least some abilities and some individuals Schaie & Baltes emphasized, in contrast, that decline does not necessarily occur for the totality of individuals or for all abilities In any case, future research should examine why some persons show a decline while other persons' abilities remain stable, and there should be further investigation of why different abilities tend to decline at different rates Schaie & Parham (143) continued the investigation of the relative impacts of cohort and age on ability decline data With equivalent age and cohort ranges of 7 years, cohort effects were generally larger than age effects until subjects were in their late 60s, at which point age effects began to predominate

AGING AND MEMORY Robertson-Tchabo & Arenberg (135) performed a FA of measures of free recall, recognition, forward digit span, dichotic digit pairs, and vigilance for healthy males in three age groups, ages 20–39, 40–59, and 60–80 Data for the pooled groups yielded four factors, interpreted as Speed of Information Processing, Secondary Memory, Attention, and Primary Memory Factor scores correlated significantly with age (older subjects having lower scores) for all factors except primary memory These findings tend to corroborate Craik's (31) conclusion that age differences in primary memory are minimal as long as stimuli are fully perceived, no reorganization is required, and attention is not divided, but that if material exceeds the capacity of primary memory and thus engages secondary memory, elderly persons tend to be somewhat deficient Friedman (51) found a loss of differentiation of memory functions in an elderly group for whom the correlation between digit and word span performances was significantly

higher than for younger subjects This result may provide an example of the similarity between the elderly and children in some respects, since abilities appear to be less differentiated in children than in young adults Such factors as motivation must, however, be considered as rival or supplementary explanations

Thomas et al (160) assessed the effects of age on speed of retrieval from long-term memory for healthy males whose ages ranged from 25 to 74 Older subjects were found to have longer picture-naming latencies, but the differences could be minimized by practice or cueing The fact that the age effect did not interact with word frequency was interpreted as showing that the pattern of results for healthy elderly persons is not the same as that for brain-damaged persons, for whom word frequency has an effect Walsh & Baldwin (174) investigated age differences in semantic memory, pointing out that most previous research has focused on episodic memory tasks, which may be less interesting to the elderly and also less ecologically valid Results using the Bransford & Franks paradigm of linguistic abstraction (but is this really semantic memory?) showed that an elderly group did not differ from a group of college students in precision of retained semantic information or in the degree to which linguistic information was integrated into holistic ideas. The elderly group was inferior to the college group on tasks involving secondary memory, as would be expected from previous research These results suggest that ecologically valid semantic memory functions may not decline with age

CONTROL OF AGE EFFECTS BY TREATMENTS Instead of accepting as inevitable a decline of abilities with age, researchers are beginning to investigate other factors that may be responsible for declines as well as to search for treatments that may prevent such a decline Birkhill & Schaie (7) assessed the effect of differential reinforcement of cautiousness in performance on PMA subtests among elderly subjects averaging 73 years of age Results showed increased performance on verbal meaning, space, and reasoning subtests when subjects were encouraged to guess answers to questions they might not otherwise answer Some reported test score declines may thus be artifacts due to overcautiousness Jordan & Rabbitt (87) examined the effects of increasing practice on the initial disadvantage of elderly subjects in serial choice reaction time to stimuli of varying complexity When subjects were unpracticed, the magnitude of the repetition effect was greater for the old than for the young subjects, but with moderate practice the magnitude of the effect was the same for both groups. Also, initially there was a complexity-by-age interaction for both number of errors and RT, older subjects being more adversely affected by increased complexity With practice, however, increased complexity was no longer a problem for

the older subjects This finding indicates the possible importance of practice variables in examining age differences in abilities

Plemons et al (130) developed a training method to modify fluid intelligence in the elderly Subjects in the treatment group received a series of eight 1-hour practice sessions on figural relations tasks over a 4 week period They were found to be superior to subjects in a control group 6 months later on a similar set of figural relations tasks, a result that suggested that the treatment effect was lasting Comparison on a less similar set of figural relations tasks, however, showed the treatment effect to be significant 1 week after the training but nonsignificant 4 weeks later This study suggests that tested fluid intelligence may be somewhat modifiable, but at least in this instance generalization of treatment effects was limited

The limited success up to now of efforts to modify abilities in the elderly should not be taken to signify that greater success cannot be achieved in the future Further research holds promise of enhancing our understanding of age-ability relationships in a major way

GENETIC AND ENVIRONMENTAL INFLUENCES

Nature-Nurture Issues

GENETIC INFLUENCES Because of the availability of recent reviews (35, 36), we need only do some updating and add a few remarks We very much agree with previous reviewers who point out that "cognitive ability is far too complex to be assessed by a univariate number such as IQ" (36, p. 180) We would insist further that even use of multiple measures of cognitive abilities such as PMA scores does not guarantee that sufficiently well-defined dimensions of cognitive IDs are being employed The great "IQ controversy" documented by Block & Dworkin (8) and persisting in current debates in the literature (82, 121, 159, 171) is thus doubly flawed, to say nothing of the numerous problems of sampling, study design, statistical models of phenotype-genotype relationships, etc with which research in this area is beset. There is even a question, raised by Roth (137), whether research using cognitive measures attends sufficiently to the "negotiated features of intelligence measurement," i e the social and sociolinguistic conditions under which measurements are taken

At the same time, we also agree with previous reviewers that "a prudent person has no alternative but to reject the hypothesis of zero heritability" of tested cognitive ability (35, p 501) We can agree with McGuire & Hirsch (116) in denying the "genetic reality" of a general factor of intelligence and in drawing attention to the possible importance of genotype-environment interactions in phenotype-variance equations, on the other hand, on the basis of the considerable evidence on the *relative* unmodifiability of cogni-

tive ability (32, 66) we find it hard to believe that the ranges of genotype reactions over different environments (e g teaching methods) can be so large as these authors appear to assume We believe the accumulated evidence suggests that in representative populations heritability of at least some cognitive abilities can be at least as high as 0 4 or 0 5 It appears, however, that the question of whether cognitive abilities differ in heritability is far from settled

On matters of the genetics of specific cognitive traits we can mention a review by Vandenberg & Kuse (170) concerned with spatial ability (or abilities?) and Vandenberg's (169) findings suggesting genetic factors in learning abilities manifested in several verbal learning tasks. These latter abilities, however, are perhaps to be identified with the Associative Memory factor identified in FA studies

ENVIRONMENTAL INFLUENCES Even if heritability values for cognitive abilities are assumed to range as high as 0 8, there is still play for the operation of environmental variables There is now impressive evidence for the role of such variables and much interest in modeling relations between such variables and dimensions of cognitive ability (18, 112, 173) Bradley et al (11) found an environmental process measure to be better than SES in predicting IQ at age 3, Trotman (163) obtained similar results for environmental measures as predictors of IQ for both white and black ninth-grade middle-class girls Kellaghan (89) found relationships between home variables and cognitive measures to be highest for scholastic attainment, somewhat smaller for crystallized intelligence measures, and still smaller for fluid intelligence measures

Several major studies of environmental intervention appear to show that cognitive abilities can be increased to a certain extent Through a program of maternal rehabilitation and cognitive stimulation, the Milwaukee Project (52) continues to report success in improving intellectual performance, language development, and behavior styles among young children identified as cultural-familial mental retarded in low SES populations McKay et al (117) reported that the gap in cognitive ability between "chronically deprived" and privileged children in a Colombian city was significantly narrowed by a treatment program combining nutritional, health, and educational features The younger the children entered the program, the greater the gains, also, the gains persisted for at least a year after the treatment ended Interestingly, the study utilized a fair number of differentiated cognitive measures, although the detailed results have yet to be reported

Zajonc (190) offered further evidence for his "confluence" model of the association between intelligence and family size and birth order, a model that surely implicates environmental influences in the form of teaching and

tuition among family members Crucial tests of this model are apparently as yet unavailable

Group Differences

SEX In a comprehensive review of sex differences in motor, spatial, and linguistic abilities, Fairweather (44) suggests that the incidence of reported sex differences is outweighed by qualifications of age, culture, sex of experimenter, etc He thinks theory development in this area is premature, especially as regards lateralization effects Nevertheless, proposals are rampant Believing that maturation rate may be a critical factor, Waber (172) found that among adolescents, early maturers were better at verbal than spatial tasks, the opposite being true for late maturers, regardless of sex Further analysis showed maturation rate related to spatial ability but not to verbal ability Late maturers were more lateralized for speech perception In a study by Welsh & Baucom (178), masculinity-femininity (as defined by self-ratings) was correlated with scores on a nonverbal reasoning test, mean scores on the latter not being significantly different between sexes

RACE Research on race differences has continued to focus on black-white differences, although interest in other racial and cultural groups has increased (61, 92, 100). There have been new looks at deficit hypotheses and attempts to investigate factors affecting group differences in test scores Finding that the notion of a perceptual defect in some black populations is still alive, Mandler & Stein (110) were unable to find solid evidence of such a defect after effects of early experiences and the characteristics of the measures used were discounted In two studies, Jensen considered the cumulative deficit hypothesis, which he called the "keystone of the rationale for compensatory education" (81, p 996) In the first study, data from younger and older siblings in black and white families in California showed a small verbal IQ decrement for blacks but none for nonverbal IQ A second study (83) using data from rural Georgia showed blacks but not whites to have a substantial decrement in both verbal and nonverbal IQ as a linear function of age Although both heredity and environment could contribute to the decrement, Jensen favors the environmental interpretation because of the superior environment for the California groups

Bridgman & Buttram (12) found strategy training to reduce race differences in nonverbal reasoning scores, but Humphreys (74) criticized their methodology and the test they used Samuel (140) investigated effects of test atmosphere, tester expectation, race and sex of tester and of subject, and SES on the performance scale of the WISC Several complex interactions were obtained, but blacks tended to score below whites across almost all conditions Samuel concluded that short-term manipulations such as these have little impact on black-white differences in WISC performance scores

APPLIED DIFFERENTIAL PSYCHOLOGY

Determinants of School Achievement

Relations between abilities and school achievement have been considered in several books Bloom (9) provided a thorough explication of his theory of school achievement and what he calls "mastery learning," describing relative influences, in interaction with characteristics of instruction, of cognitive and affective "entry characteristics" of students upon learning He claimed that IDs in aptitudes and achievement can diminish markedly under a proper regimen of teaching, a claim that tends to be supported by his own studies and one by Anderson (2) Cronbach & Snow (32) rekindled interest in aptitude-treatment interaction (ATI) research after a period of discouragement regarding the possibility of finding useful and replicable ATIs had set in

Marjoribanks (111) used complex regression models allowing for nonlinearities and interactions to examine relations among intelligence, creativity, and school achievement Measures of creativity and of nonverbal reasoning had different relations with achievement, a finding suggesting that creativity measures do not function simply as a second measure of intelligence There was no support for the view that intelligence is related to achievement up to a threshold point at which creativity overrides intelligence Instead, at high levels of both dimensions, neither is a good predictor

Drenth (37) discussed the use of psychological tests in predicting school performance in developing countries

VALIDITY STUDIES CHILDHOOD Stevenson et al (154) studied longitudinally the elementary school learning of reading and arithmetic Third grade reading and arithmetic achievement were rather highly predictable from scores on an extensive series of cognitive measures taken 4 years earlier, these scores were more predictive than teachers' ratings

VALIDITY STUDIES ADOLESCENCE AND ADULTHOOD Hakstian & Bennet (58) provided evidence of the validity of the Comprehensive Ability Battery (59) for predicting high school grades, this battery was found to compare favorably with the Differential Aptitude Tests McCall's (115) longitudinal study obtained correlations between IQs taken at different ages with educational and occupational attainment at age 26 Correlations were found to rise until about age 8 after which they remained fairly stable at about 0 5, a finding that McCall explained as due to the onset of formal schooling near age 8 Lin & Humphreys (103) found continued confirmation of their claim that the psychological nature of college achievement changes from freshman to senior year, with intellectual measures relating less to senior grades than freshman grades even when ability is measured

in the senior year Data for undergraduate and postgraduate grades suggest that the first year in a new academic learning situation represents a greater intellectual challenge than subsequent years It is not clear to what extent this is true because of more stringent course requirements in the first year of a curriculum

Schmeck et al (144) developed a self-report instrument measuring four types of IDs in learning processes that they found to be related to performance in college under study conditions. The four scales were Synthesis-Analysis, Study Methods, Fact Retention, and Elaboration Processing

CONCLUDING REMARKS THE STATE OF OUR KNOWLEDGE AND ART

Twenty-five years ago the senior author wrote the chapter on individual differences for Volume 5 of the *Annual Review of Psychology* In writing the present epilogue, he hardly dares consult what he wrote earlier, perhaps because he fears that it would be only too painfully evident that in the intervening period ID psychology has not made the substantial progress that he then looked forward to

If in 1954 he had been able to have a true vision of 1979, he would have been surprised that in 1979 people would still be arguing over what intelligence is and the extent to which it is genetically determined, that by 1979 a number of thoroughly respectable, scientifically based batteries of multifactorial ability tests for different age groups of the population had not been devised, and that in 1979 there would still be a paucity of knowledge about the rate at which different cognitive abilities develop and change over the life span under normal circumstances, or about the extent to which measured abilities are modifiable through experience, training, or instruction

It would take a lengthy excursion into the intellectual and social history of the intervening period to inquire why differential psychology has not made the kind of progress that might have been possible There has been some progress, to be sure—certainly in the sophistication of methodologies and to some extent in the accumulation of pertinent knowledge—but it is disturbing to think that even in 1979 psychologists interested in IDs find themselves in a vulnerable position Their knowledge of many aspects of the nature and determinants of cognitive abilities is still far from satisfying, and they cannot make clear and well-supported statements about the ecological relevance of these abilities or about how they might be susceptible to modification through different social and educational maneuvers

The fresh wind blowing is that of cognitive psychology and the prospect that its perspectives may be able to reform psychometrics and the theory of IDs in a radical way Previously in this article we raised the question of

whether this new trend, a Phoenix-like revival of directions that were evident 80 years ago, might succeed where the earlier movement had failed It is not yet possible to answer this question. Our review shows that the real problems and limitations of the new approaches are only beginning to be recognized, promising as they may be Already it has become clear that there is little hope of being able to replace standard psychometric instruments wholesale with series of reaction-time measurements or the like. But the new directions may prompt ID theorists to reexamine traditional assumptions, and encourage psychometricians to restructure testing instruments and procedures to take account of interactions of psychological processes and mental contents in different individuals under different conditions

The next 25 years will take differential psychology into the twenty-first century There is just a faint possibility that some of the things that seemed to be around the corner in 1954 will have come to pass by the year 2004, but if they do, it will surely be in ways that could not have been anticipated then

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