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MULTIVARIATE MODELS OF COGNITION AND PERSONALITY: THE NEED FOR BOTH PROCESS AND STRUCTURE IN PSYCHOLOGICAL THEORY AND MEASUREMENT

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Abstract

This paper calls for the development of sequential models of cognition and personality as a way of adding process to the primarily structural concerns of current multivariate models. At the same time, it points to the results of factor analysis, particularly as summarized in a hierarchical extension of Guilford's structure-of-intellect system, as a source of component variables for such sequential formulations. The need to take into account personality, developmental, and environmental variables in these sequential models is also emphasized.

Multivariate Models of Cognition and Personality: The Need for Both Process and Structure in Psychological Theory and Measurement[1]

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Over half a century of empirical research on intellectual functioning has uncovered a vast array of dimensions spanning the cognitive arena from perception through memory, reasoning, and judgment to creative production. At the same time an additional profusion of factors has emerged in studies of other aspects of personality, such as temperament, personal-social motivation, controlling mechanisms, attitudes, and interests. This very proliferation of factors has forced serious scientific attention to a search for organizing principles to lend coherence to what otherwise would be an ever enlarging conglomeration of discrete psychological components.

Several multivariate models have been proposed for this task of factorial organization, and some of them will be reviewed in detail shortly. By and large these models are primarily structural in nature in that they represent classifications or taxonomies of dimensions based upon conceptual or empirical relations among factors. It will be argued here that such structural models of consistent individual differences are not sufficient, however, for dealing with complex psychological phenomena of prime concern to theory and application, such as perception, learning, problem solving, and creativity. In brief, the structural basis should be augmented to go beyond the specification of component variables and their intercorrelations to a consideration of functional relations among the components and of their sequential operation and interaction over time in complex mental functioning.

As has been indicated, several types of multivariate models have been proposed as a basis for organizing the morass of empirical dimensions in cognition and personality (see Guilford, 1967). One is simply a dimensional model that represents the dimensions as a set of vectors in multidimensional space. Another is a hierarchical model that recognizes classes of dimensions and classes within classes, thereby taking into account the fact that some of the observed dimensions are fairly general and others quite specific, and that some are highly intercorrelated and others relatively independent. This type of model organizes the categories of dimensions very much like a tree, with broad dimensions representing limbs stemming from the trunk of a general dimension, with minor dimensions representing branches on the limbs, and still more specific dimensions twigs on the branches. A third type of model, called morphological (Zwicky, 1957), is a cross-classification of factors, a grid with intersecting categories rather than categories within categories as in the hierarchical model. A fourth type of model, which might be called sequential, represents mental functioning as an interconnected series of operations, sometimes involving feedback loops and dynamic integration over time, as in cybernetic and computer simulation models (Miller, Galanter, & Pribram, 1960; Reitman, 1965; Tomkins & Messick, 1963).

We shall begin our discussion of multivariate models of cognition and personality with a description and extension of the morphological model of intellect proposed by Guilford (1959, 1967). This model provides a cross-classification scheme for fairly specific cognitive dimensions that function at a relatively low level of generality. It primarily summarizes those dimensions derived over the years by Guilford and his co-workers in the Air Force Aviation Psychology Research Program (Guilford & Lacey, 1947) and in the Aptitudes Research Project at the University of Southern California--although most of the dimensions derived by Thurstone and others can also be classified within the framework with varying degrees of confidence and arbitrariness.

Some cognitive dimensions, however, such as inductive reasoning and perceptual speed, appear to be too general to fit unequivocally into one cell of the classification scheme, thereby suggesting the need for an extension of the system to handle broader, more complex higher-order factors that operate at higher levels of generality. Since such factors are subsumed naturally in a hierarchical model, attention will next be turned to some of the major hierarchical conceptualizations. Then in an attempt at rapprochement between the two major approaches, Guilford's system will be generalized to a hierarchical formulation which, as Guttman (1958) has pointed out, is already implicit within it. In addition, many important cognitive functions, such as reading, speaking, conservation of quantity, or problem solving, are not only complex but are sequentially ordered and cannot be adequately represented merely by sorting their component processes into the appropriate combination of cells in Guilford's design. The model will therefore also be extended to include some provision for order of components, particularly order of complexity, so that we may discuss within the same overall framework response dimensions that depend upon particular sequences of events or upon dimensions or hierarchies of mastery; e.g., where a complex performance requires the previous mastery of prerequisite or component processes (Gagné, 1965, 1968; Kofsky, 1966).

The overall model thus consists of a set of dimensions arrayed in a cross-classification scheme capable of being organized into a hierarchy of levels reflecting differential breadth of functioning and having provision for different orders of complexity. More complex psychological phenomena are viewed in terms of sequences of these component factors. The resulting formulation thus combines features of dimensional, hierarchical, morphological, and sequential models. Implications of these views for psychological measurement will also be discussed throughout.

Guilford's Structure-of-Intellect Model

Guilford's theory for the structure of intellect (SI) is an operational-informational model that postulates five intellectual operations (cognition, memory, convergent production, divergent production, and evaluation) and 24 categories of information.[2] The categories of information are further cross-classified in terms of four content categories or substantive areas of information (figural, symbolic, semantic, and behavioral) and six product categories or forms of differentiation (units, classes, relations, systems, transformations, and implications). The five operations, four contents, and six products provide a three-way cross-classification system yielding a box containing 120 cells.

As Carroll (1968) has pointed out, another way of presenting the SI model is to state that any cognitive dimension can be uniquely described by selecting one term from each of the following three columns:

Cognition (C)	Figural (F)	Units (U)
Memory (M)	Symbolic (S)	Classes (C)
Divergent production (D)	Semantic (M)	Relations (R)
Convergent production (N)	Behavioral (B)	Systems (S)
Evaluation (E)		Transformations (T)
		Implications (I)

Thus, a vocabulary factor would be described as the cognition of semantic units (CMU). Although this form of presenting the model makes it seem like a Chinese dinner menu, it does provide a convenient means for adding facets to the basic design by merely adding columns to the menu, with the proviso that each cell be described conjointly by choosing one entry from each column. Definitions of the elements of the three facets of the SI model, as given in Guilford (1967) and Guilford and Hoepfner (1966), appear in Table 1.

Guilford's attempt to organize intellectual processes into a coherent system is in the mainstream of a long and honorable tradition in the history of thought. Plato recognized two kinds of abilities, sense and intellect; other writers later added memory and still others imagination or invention. Before the fall of the Roman Empire, speech and attention were often added for consideration, and finally movement was appended (Spearman, 1927). Further increases in the list of faculties were generally obtained by subdividing these seven: sensory ability was split into visual, auditory, kinesthetic; intellect into conception, judgment, and reasoning; and so forth.

By the early twentieth century, modern lists contained a wide assortment of purported dimensions conceptualized at various levels of generality and with varying degrees of overlap. To provide some logical organization for these listings, Spearman (1927) proposed a system of three fundamental processes (the awareness of one's own experiences, the eduction of relations, and the eduction of correlates), each of which could be subdivided in terms of "(a) the different classes of relations that are cognizable, (b) the different kinds of fundaments that enter into these relations, and (c) the varying kinds and degrees of complexity in which such relations and fundaments can be conjoined." In addition to these qualitative distinctions, Spearman also proposed five quantitative "laws" to account for other sources of variability in test performance--span, retentivity, fatigue, conation, and primordial potencies (such as age, sex, heredity, and health). Some years later El-Koussy (1955; Guttman, 1958), working primarily in the area of spatial abilities, suggested that every test can be thought of as having three main aspects--content (e.g., numbers, words, figures, symbols, situations), form (e.g., classification, analogies, opposites), and function (e.g., deduction, induction, memory, visualization).

Guilford's conceptual analysis of some of the logical similarities and parallels among observed factors of intellect extends this venerable line of thinking to embrace a broader empirical array of dimensions, but a comparison of his model with earlier classification schemes suggests that still other elements might well be added, particularly in the sensory and response domains. A fourth facet could be added to the model, for instance, to represent sensory mode, with different levels on the facet referring to visual, auditory, kinesthetic, and other sensory processes. Indeed, the rudiments of this additional facet have already been included by Guilford (1967) in his attempt to classify visual, auditory, and kinesthetic candidates for the cell of the design corresponding to cognition of figural systems (CFS), as well as separate visual and auditory factors for the cognition of both figural and symbolic units (CFU and CSU).

Additional facets may also prove necessary to account for consistent individual differences due to response mode and test form: A response facet would reflect variations in mode of responding, such as oral, graphic, or motoric (pointing, marking, or performing), and a form facet would reflect variations in administration and format, such as timed vs. untimed, individual vs. group, or multiple-choice vs. free response. Individual consistencies associated with such formal characteristics of a test are sometimes called method factors (Campbell & Fiske, 1959) or response sets (Messick, 1968). They appear to reflect the operation of stylistic and personality variables in test performance and may be particularly important in the responses of young children (Damarin & Cattell, 1968; Jackson & Messick, 1958).

Regardless of the adequacy of Guilford's scheme as a theory of the structure of intellect, his classification system does provide an extensive integrated summary of known and potential factors of intellectual functioning and may thereby serve as a guide or checklist for evaluating the adequacy of coverage of experimental test batteries designed to assess the cognitive domain. As a kind of periodic table of the mind, its unfilled cells also proffer prescriptions for test construction in as yet unexplored areas of intellectual performance.

Hierarchical Models of Intellect

Although many of the factors derived empirically in various laboratories can be classified into Guilford's scheme with varying degrees of certainty, some of them, such as inductive reasoning, appear to be too broad to fit into any single cell. By appearing to span several cells, these broad factors seem to represent more general levels of functioning, which in turn subsume several of the SI cells as special cases. Such a relationship suggests a system of categories within categories, such as represented in the major competitor to Guilford's theory--the hierarchical model of intellectual functioning.

Guilford's SI scheme is a logical model, in that it derives from a conceptual analysis of perceived similarities among factors. The hierarchical formulation, on the other hand, is touted as a psychological model derived from the quantitative analysis of empirical correlations among factors. One might expect particular versions of the hierarchical model to differ somewhat as a function of the specific empirical relations summarized, but the general tree-like framework would remain the same. Both Cyril Burt (1949) and Philip Vernon (1950), for example, favor a hierarchical structure that places general intelligence (*g*) at the pinnacle with two major group factors immediately below. For Burt, these two broad group factors reflect logical thinking and aesthetic appreciation, both of which are thought to require the apprehension of abstract relations. For Vernon, the two major group factors derive from his attempts to integrate the results of several factor studies, wherein he observed that once the influence of *g* is removed, tests tend to fall into two main clusters--a verbal-numerical-educational type and a practical-mechanical-spatial-physical type. Below these broad group factors in both structures are found several minor group factors, and lower down still various specific factors.

In Burt's model, four levels of factors are represented below general intelligence: The lowest level (sensation) corresponds to simple sensory processes and simple movements, as measured by tests of sensory thresholds and reaction time. The next level (perception) consists of more complex processes of perception and coordinated movement, including a dimension of perceptual discrimination regardless of sensory content. The third level (association) embraces memory and habit formation; it contains formal factors of memory and constructive imagination, as well as content factors of imagery (reproductive imagination), verbal abilities (including both receptive and productive factors for both isolated words and connected language), arithmetical abilities, and practical abilities (including spatial and mechanical factors). The fourth level (relation), the highest below _g_, refers to thought processes of both a logical and an aesthetic type. Burt also mentions certain _general_ processes, such as speed and attention, that appear to affect mental functioning at every level. Although some of the lower-level dimensions in Burt's system, such as the receptive word factor, can be readily classified in Guilford's scheme (in this case as CMU), other dimensions, such as memory or constructive imagination (divergent thinking), appear to span several content and product categories.

Hierarchy Implicit in the SI Model

Several of the higher-level dimensions in hierarchical formulations such as Burt's sound as if they may correspond to higher-level dimensions implicit in Guilford's scheme. These implicit higher-order SI dimensions, which provide the basis for extending Guilford's system to include a hierarchy of levels, are revealed by treating the SI model as an "analysis-of-variance" design (Guttman, 1958). Since the SI model may be viewed as a 5 x 4 x 6 factorial (or facet) design, the dimensions corresponding to each cell may be considered to be a function of a general component plus three "main effects" (operations, contents, products), three second-order "interactions" (O x C, O x P, C x P), and one third-order interaction (O x C x P) unique to the dimension. Any of these main effects or interactions may be negligible in a particular case, of course. Thus, in addition to first-order factors corresponding to its 120 cells (O X C X P), the SI model generates

74 types of implicit second-order factors (30 for combinations of the 5 operations x 6 products, 20 for combinations of 5 operations x 4 contents, and 24 for combinations of 6 products x 4 contents--e.g., factors reflecting skill in cognizing figural material regardless of type of product, or skill in the divergent production of transformations regardless of type of content);

15 types of third-order factors (5 for operations, 4 for contents, and 6 for products--e.g., general memory facility regardless of form of content or type of product); and

1 fourth-order factor (general intellectual facility).

Empirical factors may occasionally turn up, of course, that appear to represent intermediate levels in the SI hierarchy, such as a single factor for cognition of both figural and symbolic units separate from cognition of semantic units or for a combination of cognition and convergent production of semantic relations. Although such complex factors may be mapped onto a combination of cells in the SI scheme, the mapping does not strictly follow the logic of the model or of this hierarchical extension. From the vantage point of the SI model, such factors are likely to have arisen because of inadequate coverage of the intellectual domain in the test battery in question, although they could be handled directly in a less logically constrained hierarchical system.

The logical nature of the higher-order dimensions in the SI model suggests that tests designed to assess them directly should be complex in nature --a measure of cognition of semantic materials, for example, should include six types of items to represent respectively semantic units, classes, relations, systems, transformations, and implications; a general measure of divergent production should include 24 types of items, one for each of the product x content combinations. Thus, direct global measures for a single facet element (like D__ or _F_), or for an intersection of elements (like CM_), could be produced by adding together appropriate items that systematically cover the remaining elements, thereby achieving test homogeneity for the higher-order dimension in question through what Humphreys (1962) has called the "control of heterogeneity." Thus, a direct measure of CM_, for example, would include a balanced array of items tapping CMU, CMC, CMR, CMS, CMT, and CMI.

Illustrative Classifications of Major Factors in Terms of the Extended SI Scheme

One purpose in emphasizing the higher-order dimensions implicit in the SI model was to see if these additional higher-order categories would improve the prospect of accommodating factors derived in other laboratories within the extended SI framework. Let us first consider some of the well-known primary factors and then speculate about the two higher-order dimensions of fluid and crystallized intelligence proposed by Cattell (1943, 1971).

Primary Mental Abilities and Other Perceptual-Cognitive Factors

Thurstone (1938, 1944) and others have uncovered several dimensions of intellectual functioning over the years that can be classified more or less readily into the extended SI model (see French, Ekstrom, & Price, 1963; Guilford, 1972). In the area of verbal ability, for instance, Verbal Comprehension appears to correspond to CMU, Word Fluency to DSU, and Ideational Fluency to DMU; Guilford's laboratory has added to the list Associational Fluency (DMR), Expressional Fluency (DMS), and a naming or labeling factor (NMU).

In the area of spatial skills, Spatial Orientation corresponds to CFS, Spatial Scanning to CFI, and Visualization to CFT. Thurstone's (1944) Speed of Closure factor represents CFU and Flexibility of Closure, NFT.

In the area of memory, Associative Memory corresponds to MSR or MSI, and Memory Span to MSU or MSS.

In the area of reasoning, General Reasoning seems to correspond to CMS and Deduction to N_I (primarily measured as NSI and NMI). Induction, as assessed by Thurstone, appears to fit in CSS, but as a general construct it seems to refer not so much to the cognition of systems (or classes or relations) as to their convergent production--for convergent production includes not only logical deduction but also the drawing of compelling inferences from input information sufficient to determine a unique answer (Guilford, 1967).[3]

Number Facility, as might be expected, is related to both NSI and MSI, but since computational skills are highly practiced and overlearned, numerical-operations tests also contain a large specific dimension not shared with non-numerical measures of NSI. Such dimensions specific to particular subsets of operations within an SI cell would appear to represent a level of functioning still lower in the hierarchy (i.e., more specific) than the factors defined by the original SI model. Wide variations such as these in the specificity and generality of empirical factors are what led to hierarchical conceptions in the first place and are just about what would be expected by a "transfer theory of abilities" (Ferguson, 1954, 1956), which holds that factors represent behaviors that happen, for whatever cultural or environmental reasons, to be learned together, along with those similar behaviors that become associated through transfer of training and generalization.

Cattell's Dimensions of Fluid and Crystallized Intelligence

Another major hierarchical theory of intellectual functioning has been proposed by Cattell (1943, 1963), who claims that there is not a single *g* but rather two higher-order general abilities, which he calls "fluid" and "crystallized" intelligence. Fluid intelligence, which is said to have a substantial hereditary component, represents "processes of reasoning in the immediate situation in tasks requiring abstracting, concept formation and attainment, and the perception and eduction of relations" (Horn & Cattell, 1966). Crystallized intelligence, which is said to owe more to the individual's learning history than to his heredity, is the "capacity to perceive limited sets of relationships and to educe limited sets of correlates as a consequence of prior learning" (Damarin & Cattell, 1968). Cattell's theory is one of the few structural models of intelligence that makes explicit provision not only for the operation of fluid intelligence but also for motivation, capacity for immediate recall, transfer of training, and relevant personality traits in the determination of crystallized achievement (Cattell, 1963; Damarin & Cattell, 1968).

Two second-order factors identified as fluid and crystallized intelligence were obtained by Horn and Cattell (1966), along with other second-order dimensions for fluency, general visualization ability, and general speediness (cf. Humphreys, 1967). The dimension of crystallized intelligence was marked primarily by Verbal Comprehension, Mechanical Knowledge, and other first-order cognitive factors, and as such it might possibly be interpreted as a higher-order cognitive dimension in the SI model (perhaps CM_ or C__). Fluid intelligence, on the other hand, was defined mainly by Induction and other reasoning primaries, thereby appearing to implicate in SI terms a higher-order convergent thinking factor. This level of interpretation, although admittedly highly speculative, is given modest support by the fact that the three other second-order intellectual dimensions obtained by Horn and Cattell (1966) also correspond fairly well to higher-order SI factors. The second-order fluency factor appears to represent DM_ or possibly a truncated D__; the general visualization factor may correspond to _F_ (virtually every task involving figural content has a loading on the dimension); and the general speed factor, marked primarily by copying and matching tests, may involve general evaluation skills.

The Need to Consider Sequences of Operations

Many complex cognitive skills, such as reading and problem solving, involve sequences of operations performed upon various categories of information, sometimes with later performance being contingent upon the prior mastery of earlier components. If such complex skills are to be systematically included in multivariate models of cognitive functioning, some provision must be made for treating order of components, including order of complexity, within a general multivariate framework.

Orders of Complexity

When a complex performance requires the previous mastery of an ordered set of prerequisite or component processes, as in cumulative learning (Gagné, 1965, 1968) or developmental progressions (Peel, 1959; Wohlwill, 1960), a dimension or hierarchy of mastery emerges that may be represented in the SI model by adding a facet for order of complexity. Order of complexity in this case refers to the increasing subsumption of simpler components into more complex ones: If t_1 is the least complex element on the facet, for example, t_2 would require everything t_1 does and more, t_3 would require everything t_2 does and more, etc.

Guttman (1958) has developed some quantitative techniques for analyzing relationships between variations in complexity and variations in test content. For tests of the same kind, variations in complexity lead to a structure that Guttman has called a simplex. For tests at a constant level of complexity, on the other hand, variations in kind of content lead to a structure called a circumplex. Variations in both complexity and kind lead to a structure known as a radex.

Orders of Sequence

Models of complex cognitive functioning should also provide some means of representing temporal sequences of processes, including feedback loops where applicable and dynamic integration over time, as in flow chart or computer simulation models (Tomkins & Messick, 1963). One prototype of such a sequential model is the cybernetic theory of behavior proposed by Miller, Galanter, and Pribram (1960), which adopts the feedback loop as its fundamental building block. This basic unit, which they have employed in the analysis of several psychological processes, is referred to in their terms as a TOTE sequence, which stands for Test-Operate-Test-Exit. This unit represents a sequence of operations in which a check is first made to ascertain whether or not a satisfactory state of affairs exists; if not, some operation is performed to rectify the situation, and a further check is made to determine the effectiveness of the operation. A satisfactory outcome would terminate the pattern (Exit), which otherwise would ordinarily continue until an acceptable test was obtained (TOTOT...TE).

The "Test" function of Miller, Galanter, and Pribram appears to be very similar to Guilford's operation of evaluation, and what they refer to as "Operate" could include in the intellectual realm the other four operations in the SI system.[4] The TOTE framework could thus be used to build up combinations of operations in sequence to represent various complex cognitive processes (Guilford, 1967). A TOTOTOTOTE sequence alternating divergent production with evaluation, for example, would provide a summary representation of trial-and-error learning.

Complex Cognitive Processes as Sequences of Operations

Factor analysis attempts to derive from consistent individual differences in complex multiply-determined behaviors a limited set of underlying component variables which in weighted combination would account for the observed variation. The extended SI model and alternative hierarchical formulations provide organized summaries of most of the factors uncovered to date. Let us next explore the extent to which these factors, particularly those representing information-processing operations, may serve as components in sequential models of complex psychological processes.

Learning and Concept Attainment

Several studies have attempted to explore relationships between learning and various intellectual functions that may contribute to the learning process, perhaps differentially at different stages of practice (Allison, 1960; Duncanson, 1964; Fleishman, 1966; Frederiksen, 1969; Stake, 1961). Bunderson (1967), for example, found that factors for three reasoning abilities as well as for visual speed related to scores on concept-attainment tasks differently at different stages of learning, suggesting that the learning process in this case might be composed of three component processes of problem analysis, search, and organization.

Dunham, Guilford, and Hoepfner (1968) studied three concept-learning tasks (one containing figural, one symbolic, and one semantic content) in relation to factors for the cognition, memory, divergent production, and convergent production of figural, symbolic, and semantic classes. They found that figural ability factors were implicated in the figural learning task, symbolic ability factors in the symbolic learning task, and semantic ability factors in the semantic learning task. Furthermore, cognition, memory, divergent production, and convergent production of classes were found to be differentially involved at different stages of learning, and somewhat different patterns of factorial relationship were produced for the three types of tasks. There was some indication that facility in the cognition of classes is a handicap early in concept learning but that it contributes more and more to success as learning progresses. The convergent production of classes tended to be more influential in the intermediate and later stages than in the beginning of learning, as did factors for the memory of classes. The divergent production of classes, on the other hand, was relatively important at the beginning of the semantic-concept task but not until the later stages of the symbolic-concept task, possibly because the greater difficulty of the symbolic task led to a greater reliance in that case upon trial-and-error strategies.

It would seem, then, that performance on a particular learning task can be represented as a sequence of complex processes, undoubtedly including motivational and personality processes, and that the relative contribution of component intellectual operations (such as cognition or divergent production) varies as a function of the stage of learning and of the difficulty or complexity of the task. The nature of the particular component factors involved also depends upon the content and form of the thing learned: Figural abilities seem likely to be implicated in learning tasks employing figural materials, for example, and the same kind of match would be expected for symbolic, semantic, and behavioral materials. Skill in dealing with classes appears to be relevant to concept attainment, as we have seen, but facility with other products might be emphasized in other forms of learning--e.g., relations and implications in paired-associate learning, systems in serial learning, and transformations in insight learning.

In reference to the SI component factors, then, learning tasks would be differentiated in terms of the content of the materials used and the product emphasized in the form of learning procedure employed, i.e., in terms of the category of information learned (the 24 C x P cells in the SI model). Thus, learning tasks may cover in a conglomerate fashion the same cells of the SI model already represented by specific ability measures, but scores from the learning task, particularly if derived separately for different stages of learning, would in addition reflect relative effectiveness in combining appropriate component skills for the achievement of a complex performance.

Similar conceptual analyses suggest that many other complex cognitive processes may also be represented in terms of sequences of factorial operations and that consistent individual differences may appear as a function of the category of information processed in each case (Guilford, 1967).

Perception and Attention

Since distinctions between "perception" and "cognition" are difficult to draw in absolute terms, most psychologists usually just admit that a blurred area of overlap exists. Consider, for example, that in the tachistoscopic presentation of words at gradually increasing exposure times, information might be extracted from the stimulus materials in stages: During the earlier brief exposures, a subject might identify only single letters and not realize until later exposures that the combination of letters perceived forms some word, whose meaning would not be comprehended until still later exposures. In Guilford's terminology, these stages of information extraction proceed from the cognition of figural units through the cognition of symbolic units to the cognition of semantic units, all of which fall properly within the domain of cognition. Guilford is willing to follow traditional usage, however, and label the cognition of form as perception, but he feels that the awareness of semantic meaning and even the realization that a form is a sign for something else would technically fall beyond the perceptual area. For Guilford (1967), then, "perception may be said to overlap cognition where figural information is concerned" (p. 252).[5]

Perceptual abilities, such as figure-ground separation, discrimination, analysis, and synthesis, appear to be roughly ordered in levels of complexity, in the sense that analysis and synthesis seem to require the prior mastery of discrimination, which in turn presupposes figure-ground separation. Because of this, one might expect these skills to be developmentally ordered, with the more complex functions developing at later ages than the simpler ones (Birch & Lefford, 1963, 1967). As we shall see in a later section, such developmental orderings should also be expected for other intellectual abilities as well, primarily because certain products of information are intrinsically more complicated than others and thereby imply more complex processing skills; e.g., systems, as complexes of related or interacting parts, presuppose facility with relations; classes, as groupings of elements, presuppose facility with units.

In SI terms, tests of figure-ground separation assess the cognition of figural units (CFU). Tests of form discrimination assess primarily the evaluation of figural units (EFU), the criterion of evaluation being identity, but variance in CFU may also be reflected to a greater or lesser degree depending upon the level of prior mastery attained by the subjects tested. If the form discrimination task involves identification after some kind of transformation such as rotation, then CFT would become a major component in performance. Form analysis, in the sense of locating in a whole figure certain isolated pieces of the figure, involves not only the cognition of figural transformations (CFT) but their convergent production (NFT) as well, with the latter function becoming more and more salient as the figures become more complicated. Form analysis of this type might therefore be a precursor of embedded-figures performance, since the dominant function in that task is also NFT (Guilford, 1967). Form analysis is said to involve a transformation, in this case a revised interpretation or use of lines, because the locating of a piece within a whole requires that lines first seen as part of the larger figure must come to be reinterpreted as part of the piece. On the other hand, form synthesis (in the sense of choosing a set of parts that may be combined to construct a standard figure) would reflect the convergent production, and possibly the cognition, of figural systems (NFS and CFS).

One of the most critical problems in the area of perception is to account for why subjects do not perceive everything in the stimulus field all the time. This problem is usually handled by introducing the concept of <u>attention</u>, which implies some kind of filtering operation underlying the observed selectivity in perception (Broadbent, 1957, 1958). In addition to the notion of selectivity, however, the concept of attention usually also involves the notion of level or intensity of involvement, in terms of degree of vigilance or arousal. Since variations in level of attention occur as a function of stimulus presentation or change and so do systematic variations in muscular, electrocortical, and autonomic responses, individual differences in the strength and habituation of these bodily responses (which together are called the orientation reaction) have come to serve as indices of attentional variables (Lynn, 1966). Thus, components of the orientation reaction, including such straightforward measures as fixation time, provide reasonably objective indices of the intensity and amount of attention even for very young children (Kagan & Lewis, 1965).

In addition to questions of how much is perceived (selectivity), for how long (duration), and with what degree of vividness (intensity), there is also the question of what is perceived--i.e., the question of the direction of attention. When we consider this latter issue, it becomes clear that the direction of attention is a function not only of characteristics of the stimuli but of characteristics of the perceiver. It is influenced by individual styles of scanning the environment and is determined to a considerable degree by the intentions and desires of the subject. This is not just the point that the S-R paradigm must be modified to include organismic variables as mediators (S-O-R), but that the organism actively selects and structures its stimulus field as a function of its needs and motives (O-S-R) (Solley & Murphy, 1960; Thurstone, 1923).

Attentional variables thus appear to fall as much in the personality domain as in the cognitive and will be treated here as part of a separate category of variables, called controlling mechanisms, that cut across the relatively arbitrary distinctions between cognitive and personal-social functioning. Controlling mechanisms, which include stylistic and strategic determinants of behavior, thus offer a basis for articulating cognitive, personal-social, and affective domains as interrelated subsystems of the total personality organization (Gardner, Jackson, & Messick, 1960; Messick, 1961). Some of these controlling mechanisms will be discussed further in a later section.

With respect to the SI model of the intellectual domain, then, attentional variables would be expected to play some role in all cells and at all levels. As previously noted by Burt (1949), attentional processes are general and influence mental functioning at every level of the hierarchy. Other authors have emphasized the role of attention in complex mental processes such as learning, and some have even claimed that attention is the major determinant of performance. Zeaman and House (1967), for example, have argued that individual differences in discrimination learning, even those between retardates and normals, are not due to individual differences in acquisition rate but to differences in attention.

Attentional processes, then, appear to involve variables that are not explicitly represented in the extended SI scheme but that very likely influence the operation of SI components in behavior. Such variables would need to be incorporated into sequential models of complex processes as moderators (i.e., as determinants of which factorial components will operate under certain circumstances) or as amplifier-attenuators of the factors.

Memory and Recall

The dimensions of memory categorized in cells of the SI model deal with the retention and retrieval of information in the same form in which it was learned and in response to the same cues in connection with which it was committed to storage. This type of retrieval has been called "replicative recall" by Guilford (1967). Within this paradigm, different dimensions of memory have been distinguished empirically in terms of the different kinds of products of information recalled. This suggests that memory storage may occur in a variety of forms, at least six according to the SI model, rather than in a single form, such as S-R connections. This possibility, which would emphasize classes and systems as well as relations and implications, offers a basis for encompassing notions of association along with notions of schema and structure within a common framework.

In addition to replicative recall, Guilford (1967) also distinguishes a type of retrieval he calls "transfer recall," in which information is retrieved from memory in response to cues not directly involved in the original learning. This type of memory retrieval is particularly relevant to divergent production, where the cues for recall are usually fairly general and cut across previous learnings and where sometimes, as in the divergent production of systems,[6] the particular elements retrieved have never even existed in combination before, let alone in connection with specific cues. In transfer recall, it is as if the subject scans his memory in search of patterns or products of information (or thinks of instances) that will match in a sufficient number of points a desired pattern defined by the given cues. It is as if the desired pattern serves as a template guiding the scanning activity, just like Duncker's (1945) "search model," with those products ultimately retrieved from memory being the ones found to match the model acceptably. The question of an acceptable match, of course, brings into play the operation of evaluation. Thus, the process of recall appears to involve a complex sequence of operations that includes divergent production and evaluation as well as the various "replicative" dimensions of memory per se, thereby taking on more the look of problem solving than of storage retrieval.

Problem Solving and Creativity

Several conceptual analyses of the problem-solving process and of the creative process have resulted in similar lists of operations occurring in sequence. Dewey (1910), for example, proposed five steps in the problem-solving process: (1) a difficulty is felt; (2) the difficulty is located and defined; (3) possible solutions are generated; (4) consequences are considered; and (5) a solution is accepted. Wallas (1926) proposed four steps for the creative process: (1) preparation, or the gathering of information; (2) incubation, or unconscious manipulation; (3) illumination, or the emergence of solutions; and (4) verification, or the testing of solutions. The final step in both series appears to correspond to the SI operation of evaluation, as does the initial step in Dewey's list, thereby suggesting that the general TOTE formulation of Miller, Galanter, and Pribram (1960) may be applicable here. With the exception of incubation, the remaining steps in both lists appear to involve cognitive factors and a blending of divergent production and convergent production. Wallas's stage of incubation provides a puzzle, however, since there is little evidence about the nature of the unconscious operations that might be involved. Guilford (1967) has suggested that incubation involves transformations of information resulting from motivationally induced interactions among stored products of information in memory.

Guilford (1967) has also proposed a sequential model of problem solving but in the form of a flow chart, rather than a list, to permit multiple feedback options. The model emphasizes the role of cognition in structuring the problem and in obtaining information from the environment and from memory and the role of production, both divergent and convergent, in generating answers. The operation of evaluation occurs repeatedly throughout the sequence. An important feature of the model is that provision is incorporated for the transmission of information from memory to the central operations of cognition and production not only through the filter of evaluation but also directly, as would be the case in the suspended judgment technique in brainstorming.

These analyses of the problem solving and creative processes as sequences of component operations are descriptive of general features rather than being predictive of specific outcomes, and as such their major value is heuristic. These models emphasize both the distinctiveness of the component processes and the sequential nature of their combination in achieving the final solutions or creative products. This suggests, on the one hand, that the various component skills should be assessed separately in order to diagnose specific proficiencies and, on the other hand, that overall aspects of the total process (and possibly its major phases) should be assessed directly to gauge relative effectiveness in combining the appropriate components in task performance.

In considering component skills in creativity and problem solving, special attention should be given to the dimensions of divergent production, for they provide the basis for the essential function of generating possibilities. These dimensions include fluency of various types, such as figural (DFU), symbolic (DSU), ideational (DMU), associational (DMR), and expressional (DMS); flexibility, in the sense of producing varied classes of responses (e.g., DMC, "spontaneous flexibility") or producing transformations (e.g., DFT, "adaptive flexibility"); originality, in the sense of producing unusual, remote, or clever responses (DMT); and elaboration, or the divergent production of implications (D–I, especially DMI, semantic elaboration). As has been noted, dimensions of evaluation also play a critical role in problem solving and creativity, and dimensions of cognition and convergent production are frequently required as well. Among the latter dimensions of particular relevance to problem solving are sensitivity to problems, or the cognition of semantic implications (CMI), and redefinition, or the convergent production of semantic transformations (NMT).

In the measurement of creativity, one common approach is to assess these various component dimensions and associated personality traits directly as a means of tapping personal qualities that might be predisposing toward creative performance (Dellas & Gaier, 1970). Another approach, which could be used jointly with the first, is to evaluate actual products for the extent to which they exhibit properties usually considered to be creative. The products might be evaluated in terms of their relative unusualness, for example, or their degree of appropriateness or fit, both internally among the parts and externally with the context. They might be judged for the extent to which they embody transformations that transcend immediate constraints or the extent to which they summarize the essence of the matter in sufficiently condensed form to warrant repeated examination (Jackson & Messick, 1965). The application of such criteria conjointly would make it possible to distinguish degrees of quality within the class of creative products--once the necessary requirements have been met for considering a product creative in the first place. In this connection, it is generally agreed that the minimal properties required for a product to be called "creative" are unusualness and appropriateness, with the latter being included primarily to rule out the bizarre and absurd (Barron, 1963; Jackson & Messick, 1965; Wallach & Kogan, 1965). This suggests that a good starting point for the assessment of creative tendencies would be measures of originality and evaluation, both of which could be derived from tasks requiring fluency in the production of uncommon (though appropriate) responses.[7]

Comparison of Sequential SI Operations with Other Summaries of Cognitive Processes

Some feeling for the provisional adequacy and appropriateness of considering SI factors as potential components in sequential models of cognition may be obtained by a brief comparison of this approach with other integrative summaries of cognitive processes. One of the most extensive of these summaries is the treatise on Children's Thinking by David Russell (1956), which distinguishes six major types of thinking: perceptual thinking, associative thinking, inductive-deductive thinking leading to concept formation or conclusion, problem solving, creative thinking, and critical thinking. As described by Russell, these six types of thinking are relatively complex processes, but in four of the six cases a particular component appears to be comparatively central. In perceptual thinking the major processes seem to be cognitive in Guilford's sense; in associative thinking the central feature is memory, particularly memory for implications and relations; in inductive-deductive thinking the dominant process is convergent production; and in critical thinking--which involves discrimination, comparison, and appraisal--it is evaluation. Both creative thinking and problem solving involve a combination of important components, but the role of divergent production is prominent in each. Thus, there is a notable match between the types of thinking described by Russell (1956) and the five operations of the SI model. The distinctions made by Guilford (1967) among the various contents and products of information processed are not similarly matched by Russell, however, who treats the materials of thinking more globally in terms of percepts, images, memories, and concepts--although Russell does consider subtypes of materials in terms of specific contents, such as percepts of space and concepts of the self, some of which could be translated into SI categories.

In another major integrative summary of cognition, Kagan and Kogan (1970) chose to structure their discussion of individual variation in cognitive processes under headings corresponding to components of the problem-solving process, which in their terms included encoding, memory, generation of hypotheses, evaluation, and deduction. Again there is a remarkable similarity between these constructs and the five operations of the SI model--memory and evaluation are represented in both schemes; encoding corresponds to cognition (with the additional operation of attentional variables); generation of hypotheses corresponds to divergent production; and deduction corresponds to convergent production. And again, consistencies in response related to different contents and products of information are not systematically treated in the Kagan and Kogan review.

It would appear, then, that the coverage of cognitive functions provided by the extended SI system is quite comparable to that of other summaries with respect to the types of psychological operations considered. It is generally more extensive and detailed than other treatments, however, with respect to the content and form of the information involved in those operations. These latter distinctions of content and form are far from trivial, for they derive not from subjective analyses of types of "knowledge," as in epistemology, but from empirical analyses of individual differences in performance, which could provide the basis for a kind of psychoepistemology (Guilford, 1967). Thus, the 24 categories of information in the content x product classification scheme not only provide a taxonomy of all the things that can be cognized, remembered, produced, and evaluated, but also a taxonomy of empirical dimensions of individual differences in information processing. Distinctions among various types of content and form were incorporated in the SI model, because it was found to make a difference at the level of individual performance whether one was dealing with classes or systems, for example, or whether the content was figural or semantic. Relationships observed to hold for one kind of content did not necessarily hold for another, and the same was true for different types of products.[8]

In this connection, special attention should be given to the distinction between behavioral information and other types of content. Behavioral content includes information involved in social interactions, where the attitudes, needs, desires, moods, feelings, intentions, perceptions, thoughts, and actions of other persons and the self are important. This separating out of behavioral information as a distinct type provides a basis for accommodating within the SI framework the repeated finding that processes of perception, memory, learning, and reasoning tend to have different properties and correlates when social or affective materials are involved, presumably because of the implication of personality dimensions and controlling mechanisms (Fitzgibbons, Goldberger, & Eagle, 1965; Messick & Damarin, 1964; Rosenhan & Messick, 1966; Thistlethwaite, 1950).

The inclusion of behavioral content in the SI model incorporates what Thorndike (1920) called "social intelligence" into the system and furnishes an ability framework for dealing with the cognitive aspects of such problem areas as person perception, social sensitivity, and self-appraisal. The behavioral abilities hypothesized by the SI model in some cases seem to be counterparts of constructs already utilized in these areas, such as "forming impressions from fragmentary cues" (CBU) or "penetrating the defenses of another person" (NBT), but in other cases the SI distinctions appear to offer new perspectives. Thus, the notion of behavioral abilities as dimensions of social information processing affords a much needed additional basis for theoretical analysis and measurement in the particularly complicated area of social cognition (e.g., see Bieri, Atkins, Briar, Leaman, Miller, & Tripodi, 1966; Bronfenbrenner, Harding, & Gallwey, 1958; Diggory, 1966; Jackson & Messick, 1963; Sarbin, Taft, & Bailey, 1960; Schroder, Driver, & Streufert, 1967; Taft, 1956; Tagiuri, 1969; Warr & Knapper, 1968).

The Interdependence of Cognition, Personality, and Development

In short, the extended SI system provides a broad integrated summary of known and potential dimensions of cognitive functioning. As such, it offers a guide or checklist for evaluating adequacy of coverage in the measurement of cognitive phenomena and provides a system of component variables for sequential descriptions of cognitive processes. One important implication of this formulation for psychological measurement is that we should not just limit attention to the measurement of specific component dimensions, but also attempt to assess the relative effectiveness of their combination in complex sequential processes such as learning or problem solving. The hierarchical features of the model serve to sensitize the investigator to questions of generalizability and point to the major kinds of response consistency that would be required for the utilization of constructs having higher levels of generality, such as consistencies across different types of content or product or operation or across various combinations of these facets (i.e., factors that span several SI cells).

The discussion up to this point has emphasized the potential fruitfulness of the extended SI system (and of the empirical factor analytic literature generally) as a source of structural components for sequential models of psychological process. There are also several problems with the approach, of course, and two serious ones will be discussed in the closing sections of this paper. The first of these problems stems from the interdependence of the cognitive domain and other subsystems of the total personality. In brief, there are many dimensions of temperament, motivation, and attitudes that influence cognitive functioning and should therefore be incorporated into sequential models of cognitive processes, but which are not embodied in the SI system. Effective sequential models of cognition, then, must include component personality variables from outside the SI framework; some obviously relevant examples of such variables for cognitive functioning are cognitive styles, which will be discussed in more detail shortly. The other problem involves the phenomena of psychological development, particularly the occurrence of developmental stages. Since the concept of developmental stages implies a sequential order, usually invariant and universal, of qualitatively different organizational structures, the question arises as to whether component factors derived from response consistencies at one stage of development are appropriately descriptive of cognitive functioning at another stage of development. In short, the issue involves the extent to which factorial dimensions are applicable across the entire age range.

Personality Organization in Cognition

The ability dimensions encompassed in the SI model essentially refer to the content of cognition or the question of "What?"--what kind of information is being processed by what operation in what form? We must also be concerned, however, with the style of cognition or the question of "How?" (i.e., the manner in which the behavior occurs), for stylistic consistencies frequently interact with content factors to influence the achievement level of performance. For this reason it is important to assess the style of response to cognitive demands as well as the content of the response, for it is dangerous to make inferences about capacity from the achievement level of performance alone (Hertzig, Birch, Thomas, & Mendez, 1968). The concept of ability implies the measurement of capacities in terms of maximal performance, whereas the concept of style implies the measurement of preferred modes of operation in terms of typical performance, but both are necessary for a full understanding of cognitive functioning (Cronbach, 1970).

Stylistic aspects of cognition reflect personality dimensions that cut across affective, personal-social, and cognitive domains and thereby serve to interweave the cognitive system with other subsystems of personality organization (Gardner, Holzman, Klein, Linton, & Spence, 1959; Gardner et al., 1960; Gardner & Moriarty, 1968; Klein, 1970). The personality dimensions of primary interest in this connection are referred to here as controlling mechanisms, which are structural dimensions of personality determining the characteristic regulation and control of impulse, thought, and behavioral expression (Gardner et al., 1959; Messick, 1961). These controlling mechanisms include such variables as cognitive styles, coping styles, attentional propensities, habitual strategies, and defenses.

Cognitive System Variables

Some of the controlling mechanisms represent dimensions of individual differences in the structural characteristics of the cognitive system itself, or more broadly of the total personality system. These dimensions primarily reflect differences in the complexity of the system and derive in large part from the thinking of Lewin (1935, 1951) and Werner (1948, 1957). Both of these theorists emphasized concepts of differentiation, articulation, and hierarchic integration in development, with Lewin in particular stressing the importance of developmental increases in the variety of units and in the independence of the parts. Several measures of individual differences in cognitive complexity have stemmed from these notions in recent years, thereby mirroring an increasing concern over system properties as controlling influences in behavior. These measures include such things as the number of different dimensions or constructs utilized by subjects in judging similarities and differences among people (Bieri, 1961; Kelly, 1955); the degree of gradation or articulation within each of these dimensions (Bieri et al., 1966; Messick & Kogan, 1966; Scott, 1963; Signell, 1966); the diversity of content exhibited in the concepts generated (Signell, 1966); the number of different groups used in sorting common objects (Gardner & Schoen, 1962; Messick & Kogan, 1963); and the abstractness vs. concreteness of conceptual systems (Harvey, Hunt, & Schroder, 1961; Schroder et al., 1967). Related concepts of psychological differentiation are also stressed in the work of Witkin, Dyk, Faterson, Goodenough, & Karp (1962) and Rokeach (1960).

Cognitive Styles

Other controlling mechanisms appear in the form of crystallized preferences or attitudes, called cognitive styles, which determine a person's typical modes of perceiving, remembering, thinking, and problem solving. For the most part, cognitive styles are information-processing habits that develop in congenial ways around underlying personality trends (Messick, 1970). As such, it is not surprising that different dimensions of cognitive style have come to be associated with particular information-processing operations--e.g., scanning with perception, leveling-sharpening with memory, conceptual style and category breadth with divergent production, field independence with convergent production, and impulsivity-reflectivity with evaluation. But this association is far from perfect, and many of the styles appear to influence information processing sequences at several points. Given the operation of such stylistic consistencies, it would be important to include these stylistic variables in detailed sequential models of cognitive functioning.

Developmental Changes in Cognition

We now turn to a consideration of the structure of the cognitive domain in childhood and the question of how far down the age scale the extended SI system might apply.

The Factorial Differentiation Hypothesis

In contrast to the notion that the major ability factors observed in adulthood may exist in rudimentary form fairly early in life is the hypothesis proposed by Garrett (1946) that a single general ability dimension is dominant in early childhood, which then differentiates in time into a few broad ability factors and later into more and more specific abilities. Guilford (1967) systematically reviewed the available evidence for and against the Garrett hypothesis and found the majority of the results to be nonsupporting. Some of the most critical evidence involved the repeated finding of differentiated abilities in very young children (ranging down to ages two and three), including the differentiation of such factors as CMU and CMS or NMU and NMS which differed in only one facet of the SI design (Hurst, 1960; Meyers, Dingman, Orpet, Sitkei, & Watts, 1964; Meyers, Orpet, Atwell, & Dingman, 1962; McCartin & Meyers, 1966). Several cognitive dimensions were also uncovered in analyses of infants and preschool children by Stott and Ball (1965), using items drawn from various standard infant and preschool scales. These investigators attempted to identify the obtained factors with SI categories, and among the 31 intellectual dimensions isolated were represented all five of the operations, as well as all four contents and five of the six products.

Such evidence suggests that at least some dimensions reflecting the major distinctions of the SI model may emerge fairly early in life. Indeed, Guilford (1967) goes so far as to suggest that the five types of operations are inherited, that "the brain is apparently predesigned to perform in the five major ways, and it may also be predesigned to handle information in the form of the different kinds of products." He thinks it more probable, though, that uniformities in the child's environment, as processed by the innate operations, are primarily responsible for the different kinds of products formed as well as for the different types of content experienced. This would suggest that certain dimensions in the SI model would be expected to develop earlier than others, because of the differential salience of particular kinds of experience early in life. The child's first experiences, for example, are probably in the form of behavioral information having reference to his own internal states, followed closely by figural information as he responds to visual and auditory inputs, then by semantic information, and finally by symbolic information. Intuitively, it also seems likely that dimensions involving certain products of information ought to develop earlier than others, such as skill in processing units before skill with classes or facility with relations before facility with systems, mainly because some products appear to be intrinsically more complex than others.

These notions accord well with the accommodation aspects of Piaget's theory (Flavell, 1963), and some of the concepts of one formulation appear to be readily translatable into the terms of the other. The sensorimotor schema of Piaget, for example, seems to correspond to a behavioral system, which developed first from behavioral units that have come to form a class of action sequences.

By and large, then, the specific Garrett (1946) hypothesis of a single general ability that differentiates over time finds little empirical support, but the more general notion that cognitive structure tends to become increasingly more differentiated (and hierarchically integrated) during the course of development, as propounded by Werner and Lewin, appears to be supported by factor analytic evidence.

Stages of Development

The immediately preceding discussion was mainly concerned with the issue of developmental continuity vs. discontinuity in cognitive structure as viewed in terms of differential psychology. Here discontinuity was indicated by changes in the number or size of dimensions over time or by changes in the meaning of dimensions, as revealed in new patterns of correlates or factor loadings (Emmerich, 1964, 1968). There is also the possibility, however, that individuals pass through a developmental sequence of qualitatively different structural organizations, usually held to be in an invariant order, which is the more classical developmental view of stage progression. Several theorists have postulated such a developmental sequence of stages, usually involving three major phases that encompass similar phenomena from theory to theory but are labeled in somewhat different terms--such as sensorimotor, perceptual, and conceptual (Werner, 1948); perceptual, imaginal, and conceptual (Thurstone, 1926); sensorimotor, preoperational, and operational (Piaget, 1950); or enactive, ikonic, and symbolic (Bruner, Olver, & Greenfield, 1966).[9]

Under these circumstances a different type of variable (and a different approach to measurement) must be added to our armamentarium--one that focuses upon an individual's stage or level on the developmental scale. The emphasis here would be upon the assessment of qualitative features that are characteristic of particular stages of cognitive functioning and upon ordered sequences of tasks capable of gauging the transition from one stage to another. Individual differences within stage might also be assessed with these tasks. Although such measures could be classified in terms of SI categories, they are not primarily intended to assess specific dimensions of cognitive functioning. Such a classification--particularly as it reflects upon representativeness of coverage in terms of content, form, and operation--may prove to be of some relevance to stage measurement, however, because of the possibility that an individual may function at different developmental levels in different cognitive areas, as in Werner's concept of mobility of developmental level and Piaget's concept of horizontal décalage. The general point here is that particular component variables and their mode of combination in sequential models of cognitive process may differ as a function of developmental level.

Interactions with Environmental Variables

Many theorists, including Piaget and Guilford, emphasize the importance of interactions with the environment for intellectual development. Although the child may start with certain innate mechanisms, such as the predispositions underlying Guilford's five operations or Piaget's invariant functions of assimilation and accommodation, the rate of progression and the variety of content in cognitive functioning appear to depend upon the extent to which these mechanisms are exercised in interaction with a varied environment (Hunt, 1961). Thus, environmental factors may also have to be included in sequential cognitive models as interactive and moderator variables.

Indeed, Ferguson (1954, 1956) has suggested that cognitive factors themselves represent domains of behavior that happen to have been learned together, along with those similar behaviors that become associated through generalization of learning and transfer. Some of the determinants of these shared learnings are developmental, in the sense that certain things are experienced together because they are appropriate to particular ages, but most of the determinants appear to be more directly sociocultural (Lesser, Fifer, & Clark, 1965). Direct evidence bearing on the transfer theory of ability development is sparse, however, because most of the training efforts studied have been limited and short term. What is clearly needed at this point to clarify these developmental and environmental determinants are "longitudinal studies in which the achievements of people with different experiences are compared" (Carroll, 1968) along with cumulative applications of a viable multivariate experimental methodology.

Epilogue

This paper has called for the development of sequential models of cognition and personality as a way of adding process to the primarily structural concerns of current multivariate models. At the same time, it has also pointed to the results of factor analysis, particularly as summarized in the extended SI system, as a source of component variables for such sequential formulations. The need to take into account personality, developmental, and environmental variables was also emphasized in the hope that the complexity of the task would be appreciated and confronted and that multivariate theorists would be challenged to engage in what Cronbach (1970) has called "deeper theoretical analysis."

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Footnotes

1. This paper was prepared for the Third Banff Conference on Theoretical Psychology in September 1971. It will be published in J. R. Royce (Ed.), Multivariate Analysis and Psychological Theory, London: Academic Press, 1973. Large sections of the paper originally appeared as part of Project Report 68-4, Disadvantaged Children and Their First School Experiences: Theoretical Considerations and Measurement Strategies, Educational Testing Service, Princeton, N. J., 1968. Some of the material was also presented in seminars when the author was a Distinguished Visiting Scholar at The Center for Advanced Study in Theoretical Psychology, Edmonton, Alberta, Canada, in March 1971. The author gratefully acknowledges an intellectual debt to J. P. Guilford, whose remarkable book The Nature of Human Intelligence stimulated this effort.

2. Guilford prefers to reserve the label "cognition" for the one operation that deals with awareness and comprehension; he uses "intelligence" to refer to all the information-processing operations together.

3. Induction is a mode of inference that goes from the particular to the general in deriving informational products from input. Its operation implies abstraction and coding, the processes of selecting or isolating certain aspects of the specific information given to form a basis for more general classification or treatment. When applied to a particular product of information, induction results in more general products of information--e.g., when applied to units, induction might yield classes, relations, systems, transformations, or implications; when applied to classes, it might yield more general classes or relations on classes

or systems; etc. The inverse mode of inference, deduction, in a sense goes from the general to the particular (or from the particular to the particular). It entails the deriving of additional information from given information and primarily refers to the derivation of implications from the information given. Induction and deduction are two ways of generating information from given information and as such are intrinsically involved in both convergent production and divergent production. In convergent production, the problem is structured with sufficient restrictions that only one appropriate product (or a small set) can be induced or deduced correctly, while in divergent production restrictions are more lax and stress is upon the number and variety of appropriate products that may be generated acceptably.

4. Guilford (1967) feels that the first T in the TOTE model is an activity of cognition although the remaining Ts represent evaluation. In line with this contention, the SI factor of <u>sensitivity to problems</u> moved from EMI to CMI.

5. It should be emphasized in this context that, at least in principle, it is not the content of the test materials that is classified in the SI model but the content of the information processed. One subject, for example, might respond to the presentation of a Chinese character as if it were a figure, another as if it were a symbol, and a third in terms of its meaning. Although we usually presume that test contents will be interpreted in the intended standard way and proceed to treat the test as a measure of X, these presumptions should be examined empirically in the light of obtained response consistencies across tests (factor patterns) and other means of inferring the respondent's subjec-

tive treatment of the materials. This point is very similar to the old caveat that tests do not have reliabilities or validities, only test responses do--and these vary as a function of subject characteristics.

6. For example, write as many four word sentences as you can where the first word begins with W, the second with C, the third with E, and the fourth with N.
7. It is sometimes possible to derive several scores from the same task to represent different dimensions of creativity, such as the number of common responses (ideational fluency), the number of uncommon responses (originality), the number of classes of responses (flexibility), and the number of inappropriate responses (evaluation). Complete reliance on this single task approach is not recommended, however, because of the potentially serious biasing effects of experimental dependencies.
8. Cronbach (1970) has questioned the empirical basis for distinguishing among factors in terms of the SI facets. Reasoning from clusters of average correlations, he concluded that the finegrained distinctions embodied in the SI system are not often supported by obtained correlational differences to the extent the model would predict. This point merits careful examination using factor analytic techniques to go beyond the inspection of correlational patterns--preferably based upon new data collected with refined instruments and test batteries experimentally structured to illuminate the issue.
9. Strictly speaking, the terms "enactive," "ikonic," and "symbolic" are used by Bruner to refer to characteristic modes of cognitive functioning rather than to developmental stages, although the three modes do emerge at different times developmentally.

Table 1

DEFINITIONS OF CATEGORIES IN THE SI MODEL

Operations	Contents	Products
C - Cognition. Immediate discovery, awareness, rediscovery, or recognition of information in various forms; comprehension or understanding.	F - Figural. Information in concrete form, as perceived or as recalled possibly in the form of images. The term "figural" minimally implies figure-ground perceptual organization. Visual spatial information is figural. Different sense modalities may be involved, e.g., visual, kinesthetic.	U - Units. Relatively segregated or circumscribed items of information having "thing" character. May be close to Gestalt psychology's "figure on a ground."
M - Memory. Retention or storage of information, with some degree of availability in the same form it was committed to storage and in response to the same cues in connection with which it was learned.	S - Symbolic. Information in the form of denotative signs, having no significance in and of themselves, such as letters, numbers, musical notations, codes, and words, when meanings and form are not considered.	C - Classes. Conceptions underlying sets of items of information grouped by virtue of their common properties.
D - Divergent Production. Generation of information from given information, where the emphasis is upon variety and quantity of output from the same source. Likely to involve what has been called transfer. This operation is most clearly involved in aptitudes of creative potential.	M - Semantic. Information in the form of meanings to which words commonly become attached, hence most notable in verbal thinking and in verbal communication but not identical with words. Meaningful pictures also often convey semantic information.	R - Relations. Connections between items of information based upon variables or points of contact that apply to them. Relational connections are more meaningful and definable than implications.
N - Convergent Production. Generation of information from given information, where the emphasis is upon achieving unique or conventionally accepted best outcomes. It is likely the given (cue) information fully determines the response.	B - Behavioral. Information, essentially nonverbal, involved in human interactions where the attitudes, needs, desires, moods, intentions, perceptions, thoughts, etc., of other people and of ourselves are involved.	S - Systems. Organized or structured aggregates of items of information; complexes of interrelated or interacting parts.
E - Evaluation. Reaching decisions or making judgments concerning criterion satisfaction (correctness, suitability, adequacy, desirability, etc.) of information. A process of comparing a product of information with known information according to logical criteria, such as identity, similarity, satisfaction of class membership, and consistency.		T - Transformations. Changes of various kinds (redefinition, shifts, or modification) of existing information or in its function.
		I - Implications. Extrapolations of information, in the form of expectancies, predictions, known or suspected antecedents, concomitants, or consequences. The connection between the given information and that extrapolated is more general and less definable than a relational connection.