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ABSTRACT

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IN SEARCH OF FUNCTIONAL MODELS OF PSYCHOLOGICAL PROCESS

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Abstract

This paper emphasizes the need to go beyond structural models of personality and intellect to develop sequential models of psychological process, particularly for such complex phenomena of prime concern to theory and application as learning, problem solving, and creativity. It is further argued that factor analysis, in a multitude of studies of cognition and personality over the past fifty years, has already delineated many relevant process variables that might serve as components in these sequential models.

Beyond Structure:
In Search of Functional Models of Psychological Process[1]

Silvan Tomkins (1962) once remarked that it seemed to him that human personality was "organized as a language is organized, with elements of varying degrees of complexity--from letters, words, phrases, and sentences to styles--and with a set of rules of combination which enable the generation of both endless novelty and the verv high order of redundancy which we call style." He went on to note that "if we had to be blind about one or the other of these types of components, we should sacrifice the elements for the rules," although "factor analysis appears to have made the opposite decision. It would tell what letters, or words, or phrases, or even styles were invariant and characteristic of a personality or of a number of personalities," but by itself it does not and cannot "generate the rules of combination which together with the elements constitute personality" (Tomkins, 1962, p. 287).

The use of language as a prototype for psychological functioning is not new. Lashley (1951), for example, pointed to the generality of the problem of syntax. He maintained that most processes of both thought and action were sequential, thereby entailing an essential problem of serial order--not just of elements but of hierarchies of organization (e.g., the order of vocal movements in pronouncing a word, the order of words in a sentence, the order of sentences in a paragraph, the order of paragraphs in a rational discourse). One of the most critical tasks for psychology is to explicate the syntax of thought and of behavior, to uncover the generalized schemata of action which determine the sequences of specific component acts, thereby moving psychological theories from the level of rhetoric to the level of grammar.

The aims of the present paper are to affirm the importance of developing sequential models of psychological process--particularly of such complex psychological phenomena of prime concern to theory and application as learning, problem solving, and creativity--and to argue, as Tomkins (1962) has already backhandedly allowed, that factor analysis in a multitude of studies of cognition and personality over the past fifty years may have delineated many important component processes for these sequential models.

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 covariation. These derived component variables, or factors, are usually interpreted in terms of common processes cutting across the various tasks and test situations aligned on the factor. These so-called "process" interpretations, however, are often relatively superficial inferences from test outcomes about possible processes that might plausibly have produced the correlated results. Since factors reflect response consistencies across tasks and test situations, theoretical interpretations of factors also typically treat them as structural variables, such as abilities and traits, which are constructs invoked to account for recurrent similarities and consistencies in behavior over time and over situations (Messick, 1961). Factor analysis thus affords a method for identifying important latent constructs, perhaps even causal variables, but it does not, in and of itself, provide functional linkages among those constructs (Royce, 1963). To do this, the ubiquitous factor analysis of concurrent covariation must be augmented by the experimental methods of the laboratory and the comparative and inductive methods of naturalistic and clinical field study (Cronbach, 1957).

In the pursuit of these functional relationships among factors, however, much depends, at least in the beginning, upon our provisional understanding of the nature of the factors. Although systematic studies extending the operation of a factor into new theoretically-relevant test domains go far to buttress the construct validity of our interpretations, such programmatic efforts are relatively rare. More usual is the general superficiality of factor interpretation mentioned earlier, a situation which should give us pause and lead us to question the viability of using such obscure entities as building blocks in functional models of complex mental processes. Carroll (1972), for example, recently lamented that "Factor analysis may be a useful technique for studying the diversity of human behavior, but the measurements on which it is based have thus far been too crude and uncontrolled to permit it to reveal its potentialities." Carried to an extreme, these concerns could lead to a marked skepticism about the construct validity of empirically derived factors as fundamental dimensions of behavioral process.

Carroll (1972) did go on to suggest, however, that "taking factor analysis into the experimental laboratory is one possible avenue that could be explored." Such an effort can be encouraged in spite of skepticism about the adequacy of factors as process constructs because the enterprise is basically an iterative one and at least partially self-correcting. The provisional interpretation of a factor influences the kinds of experiments that are undertaken to assess its functional import, to be sure, but the nature of the obtained functional involvement (or the lack thereof) also feeds back to confirm or revise the initial construct interpretation, which in turn suggests other experimental studies of function, and so on. Thus, factor analysis itself has long been held to be a powerful tool for documenting the construct validity of a <u>measure</u>--the coalescence of theoretically related measures into a factor corresponding to convergent validity, the simultaneous emergence of separate factors corresponding to discriminant validity, and the correlations among distinct factors representing relations among constructs (Messick & Barrows, 1972; Royce, 1963). What is being emphasized here is that the proposed multivariate experimental approach, by attempting to link a factor into a theoretical functional network with other factors and with situational and task variables, contributes evidence bearing directly on the construct validity of <u>factors</u>. In Campbell's (1960) terms, factor analysis is particularly valuable in establishing <u>trait validity</u> and the experimental-functional approach in establishing <u>nomological validity</u>.

This multivariate functional methodology has been applied on a number of occasions now, primarily in attempts to relate factors of intellectual ability to processes of learning. But before discussing the empirical results and the potentialities of the approach for the functional analysis of other complex mental processes such as problem solving and creativity, let us first consider the nature and sources of psychological traits, i.e., of the substantive constructs presumed to underlie the response consistencies that generate factors. The properties and determinants of these traits, their malleability and degree of interdependence with other traits in higher-order personality structures, will naturally set some limits on their range of operation and on the number and types of trait combinations that are likely to function in particular complex performances. These issues are examined at the outset to see if traits as currently conceptualized are indeed feasible candidates to consider for the roles of component (and perhaps moderating) processes in sequential models of complex psychological functioning.

Theories of the Nature and Formation of Psychological Traits

In recent years there has been a striking convergence of opinion among many psychological theorists that intellectual abilities and other traits develop out of an interaction between certain innate information-processing capabilities and the organism's environment. Piaget (see Flavell, 1963), for example, holds that all cognitive structures evolve from elementary sensorimotor reflexes through the conjoint operation of assimilation and accommodation, two invariant processes in the continuing adaptation of the organism to its environment. In this view, structures evolving later in development do not just entail the differentiation or the coalescence of earlier structures, but sometimes involve reorganizations of earlier structures into qualitatively different forms of representing the environment and regulating thought and behavior.

Guilford (1967) claims that "the brain is apparently predesigned to perform in five major ways," not two. These correspond to the five information-processing operations of cognition, memory, convergent production, divergent production, and evaluation that comprise the heart of his factorial model of the structure of intellect. Specific intellectual abilities develop through the repeated use of these five operations to process information in the individual's environment, which is purportedly so structured as to contain 24 types of information generated by the cross-classification of four types of content (figural, symbolic, semantic, behavioral) and six types of form or product (units, classes, relations, systems, transformations, implications). These generalized skills or habits develop through generalization or transfer of similar activities from task to task of a particular operation-content-product type. How well any specific ability develops depends upon how much and how effectively the individual exercises the given operation in relation to a particular content-product combination, which in turn depends upon the opportunities his environment affords him to do so and his needs to cope with those particular adaptive requirements (Guilford, 1967, p. 417).

Cattell (1943, 1963, 1971) also differentiates innate reasoning capacities, which he calls "fluid" intelligence, from those abilities that develop out of experience with a structured environment, which he puts under the rubric of "crystallized" intelligence. Fluid intelligence, which is thought 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 owes 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). Specific crystallized abilities tend to be positively intercorrelated, the communality among them generating a second-order factor representing general crystallized intelligence. Fluid intelligence also emerges as a second-order factor in Cattell's hierarchical formulation, being generated by communality among a set of differentiated primary reasoning processes.

Hebb (1949) also distinguishes a hereditary component of intelligence, which in his view is "the capacity for elaborating perceptions and conceptual activities," from an experiential component of intelligence, which is the degree to which such elaboration has occurred. Hebb further draws a distinction between learning early in life and learning later in life. Early learning is a relatively slow process of perceptual learning whereby the cumulative action of repeated stimulation builds up "assemblies" of cortical cells, which gradually become connected into "phase sequences" or organized schemas underlying complex and sequential cognition. This process of primary learning establishes a first environmental control over the association areas of the cortex and serves to facilitate later conceptual learning and problem solving through mechanisms of transfer. After small amounts of learning in early life, then, "every instance of learning is a function of the already learned organization of the subject; that is, all learning is influenced by transfer" (McGeoch, 1942).

These principles were later elaborated by Ferguson (1954, 1956), who argued that intellectual abilities are learned proficiencies whose stability is a consequence of overlearning. The typical psychological test of specific ability, then, is an assessment of performance at a crude limit of learning. Learning leading to the development of a particular ability, however, is influenced by prior learnings and previously established abilities through mechanisms of transfer. Indeed, one should expect that the most critical variables exerting transfer effects on subsequent learning would be the "abilities"--those stable prior acquisitions that have attained their limit of performance. From Ferguson's (1954) standpoint, "abilities exert their effect differentially in any learning situation; ...different abilities exert different effects at different stages of learning, and... the abilities which transfer and produce their effect at one stage of learning may be different from those which transfer and produce their effects at another stage.... As the learning of a particular task continues, the ability to perform it becomes gradually differentiated from, although not necessarily independent of, other abilities which facilitate its differentiation." Furthermore, since existing abilities thus serve to facilitate the differentiation of other specific abilities, one should expect the operation of positive transfer to produce positive correlations among abilities, thereby furnishing a simple rationale for the notion of higher-order and general factors.

One implication of this line of argument is that individuals reared in different learning environments or different cultures should develop different patterns of ability (Ferguson, 1954). Indeed, this has by and large been confirmed in a number of recent studies by Lesser and others (Lesser, Fifer, & Clark, 1965; Stodolsky & Lesser, 1967; Irvine, 1969). One might also expect, however, that higher-order factors, if they indeed reflect general transfer components underlying the mutual facilitation of several abilities, would tend to apply across a variety of specific task requirements and hence appear more similar from one cultural group to another than factors lower down in the hierarchy. Again, there is some empirical indication that this may be the case (MacArthur, 1968; Vernon, 1969). Within this learning-and-transfer conceptualization of abilities, then, differences in the factorial composition of tests from one culture to another mean that individuals in diverse cultures, by virtue of differential learning, bring different abilities to bear on the solution of an identical problem or apply the same basic abilities in quite different problem areas (Ferguson, 1954). This latter point has been strongly underscored recently by Cole and his associates, who argue that "cultural differences reside more in differences in the situations to which different cultural groups apply their skills than in differences in the skills possessed by the groups in question" (Cole & Bruner, 1971: Cole, Gay, Glick, & Sharp, 1971).

Another view of human development fairly consistent with Ferguson's is embodied in Gagné's (1968) cumulative learning model, which holds that a "child progresses from one point to the next in his development... because he learns an ordered set of capabilities which build upon each other in progressive fashion through the processes of differentiation, recall, and transfer of learning."

Although most of the present discussion of theories of trait formation has emphasized intellectual and cognitive dimensions, we may tentatively presume that personality traits can develop through largely similar mechanisms. The innate structures involved in initial interactions with the environment may differ somewhat, to be sure, with consistencies in hormonal and physiological functioning perhaps providing rudiments for dimensions of feeling, motive, temperament, and tempo. The principles of learning invoked might have a somewhat different cast as well, with an increased emphasis in the repertoire on processes other than cognitive learning, such as instrumental and vicarious learning,, operant conditioning, imitation, identification, and classical conditioning, the latter being particularly relevant to the development of affective traits (Bandura & Walters, 1963; Mowrer, 1950, 1960). It is also likely that personality traits exhibit the same kind of mutual facilitation in development as abilities do and that this facilitation occurs interactively between personality and cognitive dimensions. Indeed, personality traits may be especially important in mediating the development of cognitive skills, since certain personality consistencies may tend to develop earlier than cognitive ones, primarily because the child's initial transactions with the environment implicate affective and behavioral responses in pervasive fashion during a time when his cognitive response capabilities are gradually evolving. For example, the roles of dependency and impulsivity in mediating the development of analytical skills in cognitive-intellectual functioning has been extensively documented (Kagan & Kogan, 1970; Witkin, Dyk, Faterson, Goodenough, & Karp, 1962; Dyk & Witkin, 1965; Maccoby, 1966).

Although not all of these theories of psychological development emphasize the topic of individual differences, they all provide abundant possibilities for wide varieties of differences to emerge. There may be individual differences, for example, in the richness of innate structures and in the rate and effectiveness of key processes of adaptation, learning, and information processing. Due to differences in experience, there may also be individual differences in the sequences in which traits develop and hence possibly also in the nature of later developing traits, by virtue of their having been facilitated or mediated by different patterns of prior acquisitions. These differences in sequence and mediation also suggest the possibility of individual differences in the pattern of interrelationships among traits, with specific traits possibly being organized into different higher-order structures at different times in different individuals (Emmerich, 1968). For those theories such as Piaget's which hold that consistencies in the progressive internalization of universal forms of representation and logic lead to an invariant sequence of qualitative reorganizations or stages, there are also individual differences in the rate of stage progression, with a host of attendant differences in the meanings of variables for individuals at different development levels. This lush texture of individual differences has led some psychologists to decry the search for structure, since structural details may be differentially constituted in each individual (Wesman, 1964, 1968). They prefer instead to view intelligence, and perhaps also personality, as the summation of an individual's learning experiences at a given moment in time. But complex structure and variability in structure are not the absence of structure, nor are they inconsistent with the notion of individuality. Each individual may differ in profound ways from every other individual, but at the same time the occurrence of patterns of response consistency generates the notion of common traits or factors and of common higher-order organizations (at least for specific types of people) as a means of accounting for those consistencies. And the resolution of these response consistencies, using such methods as factor analysis, has provided us over the years with a vast array of organismic variables of potential importance for understanding ongoing psychological functioning.

These variables have been conceptualized in a variety of ways, but a recent convergence of opinion about their nature has important implications for their utility in models of complex process. To begin with, all of the theories of psychological development just discussed, in spite of important differences that were glossed over in this cursory treatment, have certain common implications concerning the nature of the structures or traits formed--or at least find these implications congenial or admissible within their general theoretical framework. All of these theories, for example, are counter to earlier traditional notions of fixed intelligence or temperament as well as to notions of genetically predetermined development (J. McV. Hunt, 1961). They all emphasize the importance of interaction with the environment. They all suggest that cognitive structures and other traits represent cumulative processes or developed capacities[2] that, for whatever cultural or environmental reason, happen to have been learned together, along with those similar processes that become associated through assimilation, generalization, or transfer. Although many of the determinants of these shared learnings are socio-cultural, some are also developmental, in the sense that certain things are experienced together because they are appropriate to particular ages or because their processing depends upon the prior development of prerequisite structures, a point particularly emphasized by Piaget. Thus, of the three mechanisms proposed by Tryon (1935) to account for intercorrelations among different psychological measures--namely, overlap of psychological components, correlation between independent environmental fields, and correlation between independent gene blocks--these theories emphasize the first two sources of correlation as well as interactions between them. The last source is by no means denied, however, nor are the pervasive cultural factors which may operate to shape the functioning of all three of these formative mechanisms (Anastasi, 1970).

It is also consistent with all of these theories to view many of the emergent structures and traits as information-processing variables (J. McV. Hunt, 1961). This has been made explicit by Guilford (1967), as we have seen. Fleishman (1967a) has also proposed an information-processing model of human learning in which abilities represent various capacities for processing different kinds of information. Furthermore, Neimark (1970) has recently outlined an information-processing approach to thinking and its development, in which she translated many of Piaget's constructs into computer terminology.

Nor are abilities the only traits that may be usefully conceived in information-processing terms. Cognitive styles, for example, have been conceptualized as information-processing habits that develop in congenial ways around underlying personality trends (Messick, 1970, 1972). These styles appear in the form of crystallized preferences, attitudes, or habitual strategies which determine a person's characteristic modes of perceiving, remembering, thinking, and problem solving. They include such variables as category-width preferences, scanning, leveling vs. sharpening, impulsivity vs. reflectivity, constricted vs. flexible control, and field-dependence vs. field-independence. Although they function to control and regulate the course of information processing, their operation may possibly be in the service of deeper dynamic themes, for "anxiety over error, attention distribution, expectancy of success and failure, and vulnerability to distraction are central to many of the test procedures utilized" in their assessment (Kagan & Kogan, 1970). Other controlling mechanisms of personality, such as coping styles, attentional propensities, and even defenses, are also active in the regulation and control of impulse, thought, and behavioral expression and might thereby similarly serve as component processes or moderator variables determining the nature and sequence of information processing (Abelson, 1963).

From this brief review of the psychology and development of traits or factors, it should be clear that many psychological traits, especially cognitive abilities and personality control mechanisms, have several characteristics that make it plausible to consider them as potential components in functional models of complex mental processes. To begin with, they are not considered to be fixed entities, but rather variables responsive to environmental impact. Indeed, they are conceived as processes of continuing adaptation to environmental demands. One might expect them, therefore, when cast as dependent variables, to display appropriate functional responsiveness to experimental treatments and to critical variations in tasks and conditions. At the same time, however, because of cumulative learning, their operation becomes progressively more stable, so that one should also anticipate increasing consistency, particularly across noncritical variations in tasks and conditions. This stability is a marked advantage when these traits are cast as independent variables in the prediction of complex performance outcomes or as mediating variables in the facilitation of other processes or traits. Finally, as we have seen, many traits are directly interpretable in terms of information-processing operators, making them particularly compatible candidates for inclusion in sequential models of complex cognitive processes such as learning and problem solving, which have intrinsic information-processing aspects. Let us now turn to a consideration of such complex sequential processes and of the functional contribution of psychological traits or factors to their performance.

Traits as Functional Components of Complex Sequential Processes

Learning

Most of the empirical applications of the multivariate experimental approach discussed earlier have been in the area of learning. This is a particularly fruitful area for such a foray, because one of the key concepts in the field of learning--namely, transfer--provides a direct basis for developing a functional link between traits, especially abilities, and performance outcomes. Ferguson (1956) formalized the notion of transfer in terms of a four-variable model, which could be simply generalized to multiple variables. The basic components are measures of performance, x and y, on two tasks and measures of the amount of training or practice, t_x and t_y, on the same two tasks. The general transfer function $y = f(x, t_x, t_y)$ simply means that performance on one task is a particular function of performance on another task and of the amounts of practice on the two tasks. It is the special cases of this expression that are of interest.

If x and y are the same task, the expression reduces to $y = f(t_y)$, a general form for conventional learning curves, relating performance on a task to the amount of practice on that task. If x and y are tasks of the same type but are not identical, the transfer effect is usually discussed in terms of "learning sets" or learning to learn (Harlow, 1949) and is sometimes taken to indicate the development and use of information-processing strategies or skills in problem solution (J. McV. Hunt, 1961). Whiteman (1964) highlighted learning sets as a possible mechanism in the formation of ability factors, but from Ferguson's standpoint they represent only a special case of more general transfer effects operative in ability development.

If t_x and t_y are very large so that additional practice produces little effect upon performance, then measures of x and y at this limit of learning represent abilities, related by the function $y = f(x)$. Correlations between tests of ability are thus seen as correlations between performances that have attained a crude stability through over-learning. The transfer function of particular interest in the present context is $y = f(x, t_y)$, which relates ability x to learning on y, i.e., to changes in performance on y as a function of practice.

We will next review briefly four major multivariate experiments that investigated relationships between abilities and learning performance at successive stages of learning. The usual procedure employed in these studies was to compute factor loadings for the learning performance measure on each ability factor to indicate the degree of transfer or functional involvement of the ability at a particular stage of learning. These ability loadings were computed separately for learning performance at each stage of practice and were then usually plotted as a function of practice to display the differential involvement of ability factors throughout the course of learning.

Striking empirical support for this transfer theory of ability functioning has been provided in the area of psychomotor learning by Fleishman and others, who demonstrated that the contribution of ability factors to performance on psychomotor learning tasks changes substantially with practice. In general, it was found that non-motor abilities such as spatial relations and visualization were relatively important in early stages of learning and that motor abilities such as coordination and rate of movement became predominant in later stages of learning, along with a systematically increasing specific task factor (Fleishman & Hempel, 1954, 1955; Fleishman, 1957, 1960, 1965; Fleishman & Rich, 1963; Kohfeld, 1966). Other important studies relating abilities to learning parameters include those of Allison (1960); Duncanson (1964); Dunham and Bunderson (1969); Games (1962); Manley (1965); and Stake (1961).

Bunderson (1967) investigated the contribution of several specific abilities to concept learning. He not only found their contribution to be substantial but noted that different abilities were implicated in different ways throughout the course of learning in such a way as to suggest three major phases of concept learning--a problem analysis phase, a search phase, and an organization phase. Verbal Reasoning, which was found to transfer early in practice, was identified with a problem analysis process, and General Reasoning, which transferred mid-way in practice, was identified with an organizational or integrating process; Induction and Figural Flexibility were related to a search process. These constructs of analysis, search, and organization are similar to high-level heuristic processes common to a number of computer simulation models. If, as Simon and Newell (1964) have suggested, these common information-processing heuristics may serve as building blocks for theories of complex behavior in many domains, then the results of the present study point to the possibility of including differential ability processes not only in fine-grained simulation models of concept learning but in models of other psychological processes as well.

The results of Bunderson's (1967) study also suggest the need for different types of classification schemes for factors to elucidate their role in complex learning. Although various hierarchical models and the three-way grid of Guilford's structure-of-intellect may serve to characterize interrelationships and parallels among factors, Bunderson proposed that some such functional distinction as between "input" factors, "process" factors, and "strategy selection" factors might be more useful in guiding future experimental work on complex mental functioning. In a similar vein, Fleishman (1967b) has also called for the development of a taxonomy of human abilities that would link laboratory with realistic human tasks, in the hope of fostering more dependable generalizations of experimental data.

Dunham, Guilford, and Hoepfner (1968) studied three concept-learning tasks (one containing figural, one symbolic, and one semantic content) in relation to ability factors for the cognition, memory, divergent production, and convergent production of figural, symbolic, and semantic class respectively. They found that figural abilities were implicated in the figural learning task, symbolic abilities in the symbolic learning task, and semantic abilities in the semantic learning task. Factors of cognition, memory, divergent production, and convergent production of classes were all involved, but differentially at different stages of learning, producing somewhat different patterns of relationship 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 it was not implicated 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.

From this study it would seem that the nature of the particular abilities involved in the process of concept learning 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. Thus, structural models of factor interrelationships, such as Guilford's structure-of-intellect (SI) formulation, do not appear to be wholly irrelevant to the role of abilities in complex learning. In this connection, learning tasks would be classified according to the degree to which they were differentiated with respect to the content of the materials used and the form of response or product emphasized in the type of learning procedure employed; i.e., in terms of the category of information learned (the 24 content x product cells in the SI model). In this way, learning tasks might be found to cover in a conglomerate fashion the same cells of the SI model already represented by specific ability measures, but performance 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.

A milestone study in this multivariate experimental probing of complex learning processes was published in 1969 by Carl Frederiksen. Frederiksen (1969) not only attempted to relate specific cognitive abilities to components of verbal learning, but he examined their operation separately under three instructional conditions designed to be differentially amenable to different cognitive strategies. He also assessed the strategies actually employed by the subjects in learning and found that they clustered empirically into five major types--attempts to organize the list by grouping, the use of semantic mnemonics, attempts at active sequential organization, the use of active vs. passive order-preserving mnemonics, and active attempts at recategorization or modification of ineffective strategies. Frederiksen found that mean strategy choice was markedly different under the three conditions of learning and that relationships between strategies and components of learning performance were different in the three conditions. Interestingly enough, two of the conditions were fairly similar in component performance and in average learning curves, but were quite different in strategies used and in abilities implicated, thereby illustrating the enormous complexity of process glossed over by average learning curves. Strategy choice was not only a response to characteristics of the task, however, but was also partly a function of the individual's abilities. Specific abilities were found to be related to different components of learning in different ways under the three conditions, their operation being mediated by cognitive strategies. These results extend into the learning domain previous findings by French (1965), who showed that the factorial structure of a set of cognitive tests varied widely as a function of the problem-solving strategies or styles of the respondents.

Frederiksen's (1969) study underscores the futility of attempts to relate ability measures to overall or average indices of learning performance. It also highlights the need to open up conceptualizations of complex learning processes to include not only components of information-processing abilities but also higher-order information-processing heuristics such as plans and strategies, which in turn may implicate variables of personality and cognitive style. One important possibility in this regard is that higher-order traits may enter into sequences not only as components (a simple sequential model), but as organizers of components (a hierarchical personality model).

It seems clear at this point that the functional models of complex mental processes that we seek must themselves be very complex and be cast in process terms. We have long looked to computer simulation as a viable means for developing such models, and if the pay-off has been slow in coming, it is partly because computer models demand a deeper theoretical analysis than our current superficial experiments can support (E. Hunt, 1968). In any event, computer simulation may be the only approach that is up to the task, for we need some means of coping with a massive increase in the complexity of relationships and in the multiplicity of influences affecting outcomes and predictions. We aspire to go beyond lists or sequences of operations, however long and however embellished with feedback loops, to develop working computer models that provide dynamic integration over time in the resolution of constantly changing and probabilistic forces (Tomkins & Messick, 1963; Abelson, 1968).

Problem Solving and Creativity

Let us next briefly examine another area of complex mental functioning--namely, problem solving and creativity--to see if the multivariate experimental approach employed in studying learning processes might have wider applicability. For this approach to be applied in the same way, two key conditions must be fulfilled in the new area: first, the problem solving or creative process must be sequential, or extended in time, and amenable to interim measures of performance at intermediate stages; and second, a number of traits or factors must have been delineated that might appropriately function as component processes. (Other multivariate experimental designs could of course be applied without these conditions being met.)

With respect to the first point, there is indeed a long history of conceptual analyses of problem solving and creativity that have produced several highly 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. In the characterization of a real problem solving situation, of course, these component steps may have to be iterated in various combinations rather than occurring in a fixed succession, as might be inferred from the simple listing. At least on the surface, then, the first condition appears to pose no problem. Not only are these processes conceived as sequential, but with the exception of "incubation" all of the steps on both lists appear to implicate well-established cognitive factors.

Furthermore, many of the steps themselves are reminiscent of those heuristic information-processing building blocks that Simon and Newell (1964) thought to be generally applicable in several domains. They bring to mind the problem analysis, search, and organization phases of Bunderson's (1967) study, for instance. To be sure, it is not surprising to encounter such surface carryover across the two domains, for many of the learning studies reviewed earlier, particularly those of concept attainment, involved tasks that might just as well have been treated as problem solving exercises.

Wallas's stage of incubation provides a puzzle, however, for little is known 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, thereby making explicit the possibility of multiple feedback options. The model emphasizes the role of SI factors of cognition in structuring the problem and in obtaining information from the environment and from memory, as well as the role of both convergent and divergent production 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.

Thus, problem solving and creativity do appear to be sequential processes extended over time, but the ancillary requirement that performance measures be feasible at several intermediate stages is not as clearly met and requires additional developmental effort. In regard to the second condition, numerous factors have indeed been uncovered, mostly in Guilford's aptitude research program, that provide plausible candidates to function as component skills in problem solving and creati·e processes. Special attention should be given to the dimensions of divergent production, for they provide the basis for the essential function of generating alternatives or possibilities. These dimensions include <u>fluency</u> of various types, such as figural (DFU in Guilford's terminology), symbolic (DSU), ideational (DMU), associational (DMR), and expressional (DMS); <u>flexibility</u>, in the sense of producing varied classes of responses (e.g., DMC, "spontaneous flexibility") or producing transformations (e.g., DFT, "adaptive flexibility"); <u>originality</u>, in the sense of producing unusual, remote, or clever responses (DMT); and <u>elaboration</u>, 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 addition to attempting to relate such cognitive factors to performance measures at different stages of problem solving and creative production, one might also try to relate them to different qualities or dimensions of creative products. That is, we could evaluate accual products judgmentally 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). Individual differences in these judgmental scores could then be correlated with scores on cognitive factors to elucidate the involvement of cognitive processes in the production of different levels and aspects of creative accomplishment.

It would thus appear that the complex processes of creativity and problem solving offer potentially fruitful territory for the application of multivariate experimental designs aimed at clarifying the functional roles of cognitive and personality factors as component processes in the overall dynamic sequences. Other complex processes such as memory and recall may also prove to be similarly amenable to analysis in terms of sequences of component factorial processes (Guilford, 1967; Messick, 1972).

The Person in Models of Process

The overall line of evidence reviewed here, while not overwhelming, appears to be sufficiently cumulative to suggest the viability of the proposed strategy and to spur us on to next steps. To recapitulate briefly, certain basic human functions, such as learning and problem solving, appear to be analyzable into complex sequences of component processes, with the course of events sometimes being organized in terms of higher-order heuristic processes such as strategies. Furthermore, many factors of cognition and personality derived from studies of consistent individual differences appear to represent information-processing capabilities and styles, thereby qualifying them for consideration as component processes in these complex sequences. Evidence for the functional involvement of such factors in determining the complex performances in question has been accruing and now promises a developing groundwork for the ultimate step of detailed model building. The level of deep theoretical analysis required for formulating functional models of psychological process, especially computer simulation models, is far removed, however, from the present state of limited evidence on the nature and degree of functional relationship linking cognitive factors to learning or problem solving. This suggests the need, for some time to come, to intensify the multivariate experimental investigation of these domains to explicate the functional intricacies of the processes.

As we look ahead to the nature of possible functional models, it would be well to keep in mind that our purview with respect to the involvement of personality in these complex processes has been quite limited. We have examined the functional involvement of cognitive and stylistic factors in learning tasks set by the experimenter under conditions varied by the experimenter, and even here we find that the subject restructures the problem in terms of his own strategies (Frederiksen, 1969). Just imagine how much more complicated it might be under more realistic circumstances, where learning and problem solving occur in the service of personal goals and motives. This is not just the point that the range of organismic variables serving as mediators in the S-O-R paradigm should be broadly inclusive of personality and motivational variables, but rather that the organism actively structures its own field of learning and the problems that it chooses to confront as a function of its needs and motives and values, which seems more akin to an O-S-R paradigm (Thurstone,1923; Solley & Murphy, 1960). In terms of our opening analogy, this would imply that our attempts to probe the syntax of thought and action in an effort to develop psychological theories at the level of grammar should be expanded to include the impact of personal meaning--to embrace, as it were, the semantics of human endeavor.

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Footnotes

[1] Presidential address delivered at the annual meeting of the Psychometric Society, held jointly with Division 5 of the American Psychological Association, Honolulu, Hawaii, September 5, 1972. The author wishes to thank Walter Emmerich for his clarifying comments and conceptual contributions to this work.

[2] Strictly speaking, psychological development in these theories, particularly Piaget's, is not really cumulative in the sense of an accretion of successive additions to an ever enlarging base. Rather, it is cumulative in the more general sense that later structures, even those entailing qualitative reorganizations, are based upon and utilize the stuff of earlier structures.