

The Essential
Sternberg
Essays on
Intelligence,
Psychology,
and Education

Editors

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Preface

Robert J. Sternberg (Bob Sternberg) is the foremost psychological and educational theorist, researcher, and reformer of his time. He left an endowed professorship at Yale University to become the Dean of the School of Arts and Sciences and Professor of Psychology and Education at Tufts University to bring his ideas to a hands-on, real-life situation. He is changing the admissions process at Tufts in ways that have been called “bold,” “innovative,” and “exciting.”

About This Book

The goal of this book is to compile a “best of” Sternberg’s work. As his research is being applied more and more and the impact of his writing extends to thousands of people, a new audience for his work and writings is developing. This book provides a core collection of what he and his colleagues think are his best papers, tracing the evolution of his popular theory of successful intelligence and his thoughts on the educational process.

We have selected, in consultation with Bob and our colleagues, what we believe to be some of the best writing, research, and theoretical contributions by Sternberg. In Section I, we’ve selected three different articles, from 1980, 1984, and 1999, that show the development and progression of Sternberg’s theory of successful intelligence. In Section II, we include articles on each one of the three components of Sternberg’s theory: creativity, practical intelligence, and analytic reasoning. Section III describes Sternberg’s theory as it relates to the classroom, with a theoretical piece and two empirical articles that focus on how the theory of successful intelligence can be used to improve student performance and supplement traditional exams. Section IV includes two recent essays that directly test the theory in college admission settings. Section V presents two articles about Sternberg’s most recent theory, the WICS (wisdom, intelligence, and creativity, synthesized) model, with its new focus on wisdom. Finally, Section VI offers brief writings by Sternberg that yield insight into his opinions on different questions in psychology.

We hope that this collection provides a comprehensive yet convenient overview of Sternberg’s work. For those familiar with Sternberg’s theories and research, this book represents a chance to read his original articles. For those unfamiliar with Sternberg’s legacy, this book offers a rare treat—the chance to see the evolution of one of the great thinkers of our time.

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Section I

An Introduction to the Theory of Successful Intelligence

Sketch of a Componential Subtheory of Human Intelligence

1

Robert J. Sternberg

This chapter presents a sketch of a componential subtheory of human intelligence. This theory attempts to account for many of the empirical phenomena reported in the literature on human abilities. In view of the obvious ambitiousness of this attempt, I wish to make explicit two caveats implicit in the title of the chapter.

First, the chapter presents a sketch, not a finished product. Some of the proposals are clear and reasonably well articulated; others are fuzzy and in need of further articulation. Some of the proposals have solid empirical backing from my own laboratory or the laboratories of others; others have only the most meager empirical backing, or none at all. These last proposals are intended as stimuli for future research, rather than as generalizations from the results of past research. It will be many years before the theory as a whole will have been subjected to thorough empirical testing. In the meantime, it suggests possible directions for empirical research. As time goes by, the outline should become sharper and the shading better articulated.

Second, the chapter presents a limited subtheory, not a comprehensive, full theory of intelligence. Even if the proposals were close to their final form, they would still constitute a subtheory, because there is almost certainly much more to intelligence than is covered by the scope of the present proposals. They do not deal at all with issues of motivation, initiative, and social competence, and they deal only minimally

with issues of creativity and generativity (see Sternberg, 1981a). There are many other issues that are dealt with only minimally, or not at all. The subtheory evolved from research on reasoning, problem solving, and their acquisition. Hence, its most immediate applicability is probably to those aspects of intelligence that derive from these domains; and even here, the coverage of the theory is certainly incomplete.

Having expressed these two caveats, I proceed to a consideration of the theory's predecessors.

Alternative Basic Units for Intelligence

Theories of human intelligence have traditionally relied on some basic unit of analysis for explaining sources of individual differences in intelligent behavior. Theories have differed in terms of (a) what is proposed as the basic unit; (b) the particular instantiations of this unit that are proposed somehow to be locked inside our heads; and (c) the way in which these instantiations are organized with respect to one another. Differences in basic units have defined "paradigms" of theory and research on intelligence; differences in instantiations and organizations of these units have defined particular theories within these paradigms. What are these alternative units, and what are the theories that have incorporated them? Three alternative basic units for intelligence will be considered: the factor, the S-R bond, and the component (or elementary information process). Each of these basic units leads to a somewhat different conception of what intelligence is and how it is constituted.

The Factor

In most traditional investigations of intelligence, the basic unit of analysis has been the factor. The paradigm in which this unit has been defined and used is referred to as the "differential," "psychometric," or "factorial" paradigm. Factors are obtained by "factor analyzing" a matrix of intercorrelations (or covariances) between scores on tests of measures of ability. Factor analysis tends to group into single factors observable sources of individual-difference variation that are highly correlated with each other, and to group into different factors observable sources of variation that are only modestly correlated or not at all correlated with each other. These new groupings are each proposed to represent unitary, latent sources of individual differences at some level of analysis. Theorists generally agree that other levels of analysis, in which factors would either be further subdivided or further combined, would be possible as well.

What, exactly, is a factor? There is no single, agreed-upon answer to this question. Thurstone (1947) noted that "factors may be called by different names, such as 'causes,' 'faculties,' 'parameters,' 'functional unities,' 'abilities,' or 'independent measurements'" (p. 56). Royce (1963) added to this list "dimensions, determinants, . . . and taxonomic categories" (p. 522), and Cattell (1971) has referred to factors as "source traits."

Factor theorists have differed with respect to the particular factors purported to be basic to intelligence. (See Brody & Brody, 1976; Butcher, 1970; Cronbach, 1970 for reviews.) Spearman (1927) suggested that intelligence comprises one general factor that is common to all of the tasks that are used in the assessment of intelligence, and as many specific factors as there are tasks. Holzinger (1938) suggested the need for

Sketch of a Componential Subtheory of Human Intelligence

a third kind of factor, a group factor common to some but not all of the tasks used to assess intelligence. Thurstone (1938) proposed that intelligence is best understood in terms of multiple factors, or primary mental abilities, as he called them. He tentatively identified seven such factors, leaving open the possibility that more would be discovered later: verbal comprehension, word fluency, number, reasoning, spatial visualization, perceptual speed, and memory. Guilford (1967) has proposed a theory encompassing 120 factors formed by crossing five operations, six products, and four contents. The concept of a hierarchical theory can be traced back at least to Burt (1940), and more sophisticated hierarchical factor theories have been proposed by Jensen (1970), who reviews a variety of hierarchical theories, and by Vernon (1971). In Jensen's theory, intelligence is viewed as comprising two levels: associative learning ability (called Level I) and conceptual learning and problem solving (called Level II). Spearman's general factor is seen as corresponding to Level II intelligence. In Vernon's theory, factors are proposed to be of four kinds: (1) a general factor, encompassing all tasks; (2) major group factors, including a verbal-educational factor and a practical-mechanical factor; (3) minor group factors; and (4) specific factors. Humphreys (1962) has proposed a sophisticated hierarchical theory that combines aspects of the Burt-Vernon tradition of hierarchical factor analysis with aspects of Guttman's (1954) facet analysis, in which intelligence is subdivided in terms of logical dimensions. Cattell (1971) and Horn (1968) have proposed a theory according to which the general factor noted by Spearman (1927) is alleged to comprise two subfactors: crystallized ability, measured by tests such as vocabulary and general information; and fluid ability, measured by tests such as abstract analogies and abstract series completions. Horn and Cattell (1966) also extracted subfactors representing visualization and cognitive-speed abilities.

The S–R Bond

Stimulus-response (S–R) theorizing has had less influence on theory and research in intelligence than have the other units we are considering, and hence will be treated more briefly. The role of the S–R bond concept in theorizing about intelligence can be traced back to Thorndike (1911; Thorndike, Bregman, Cobb, & Woodyard, 1928) who, like subsequent S–R theorists, viewed intelligence primarily in terms of the ability to learn. In early S–R theorizing, intelligence was understood in terms of the buildup of simple S–R bonds. A more sophisticated and variegated view has been proposed by Gagne (1970), who has suggested that there are eight kinds of learning, which differ among themselves in both the quantity and quality of S–R bonds involved. From simplest to most complex, these are signal learning (Pavlovian conditioning), stimulus-response learning (operant conditioning), chaining (complex operant conditioning), verbal association, discrimination learning, concept learning, rule learning, and problem solving.

The Component

A component is an elementary information process that operates on internal representations of objects or symbols (Sternberg, 1977; see also Nevell & Simon, 1972). The component may translate a sensory input into a conceptual representation, transform one conceptual representation into another, or translate a conceptual representation

into a motor output. What is considered elementary enough to be labeled a component depends on the desired level of theorizing. Just as factors can be split into successively finer subfactors, so components can be split into successively finer subcomponents. Thus, no claim is made that any of the components referred to later in this chapter are elementary at all levels of analysis. Rather, they are elementary at a convenient level of analysis. The same caveat applies to the proposed typology of components. Other typologies could doubtless be proposed that would serve this or other theoretical purposes as well or better. The particular typology proposed, however, has proved to be convenient in at least certain theoretical and experimental contexts.

A number of theories have been proposed during the past decade that might be labeled, at least loosely, as componential. Hunt (1978; Hunt, Frost, & Lunneborg, 1973; Hunt, Lunneborg, & Lewis, 1975) has proposed that individual differences in the efficacy of execution of information-processing components such as those found in simple tasks studied in the cognitive psychologist's laboratory are a significant source of individual differences in higher-order verbal ability as measured by standard tests of intelligence. For example, Hunt has found that in the matching task of Posner and Mitchell (1967), the difference in response latency between a name match ("Aa" match in name but not in physical appearance) and a physical match ("AA" match in physical appearance as well as in name) is moderately correlated across subjects (about $-.30$) with scores on a verbal ability test. Carroll (1976) has done a compelling armchair analysis of a number of factors from standard psychometric ability tests in terms of some of the information-processing components that might be sources of individual differences in these factors. Jensen (1979; Jensen & Munro, 1979) has found that simple reaction time and movement time in an elegant choice reaction time paradigm are moderately correlated with scores on the Raven (1965) Progressive Matrices. Pellegrino and Glaser (1979) have found that certain components of information processing seem to be common across inductive reasoning tests such as verbal analogies, geometric analogies, and letter series extrapolations. Snow (1979) has suggested that individual differences in intelligence can be understood in part in terms of differences in latencies of component execution, as well as in terms of differences in choices of components, in strategies for combining components, and in global aspects of information processing. Campione and Brown (1979) and Butterfield and Belmont (1977) have shown that mental retardation can be understood at least in part in terms of the retarded individual's tendency to select strategies that are nonoptimal for task performance.

Interrelations Among Units

The alternative units discussed previously are not mutually exclusive; on the contrary, they are complementary. Stimulus-response theorizing concentrates on the external or environmental contingencies that lead to various kinds of responses, whereas factorial and componential theorizing concentrate on the internal effects of these contingencies. Factorial models tend to be structural ones, although they often contain clear implications for understanding information processing; componential models tend to be process ones, although they often contain clear implications for understanding how information is structured. I propose, along with Carroll (1976) and others, that factors can be understood in terms of components. But components should not be viewed as superseding factors in that for at least some educational purposes (such

as predicting performance), factors are probably still the preferred unit of analysis. For other educational purposes (such as training performance), components are probably the preferred unit of analysis (see Sternberg, 1981).

Certain of the theories noted earlier help place interrelations among alternative units of analysis into sharper perspective. Spearman's (1927) general factor, for example, has often been understood in terms of individual differences in people's abilities to implement Spearman's (1923) three principles of cognition—apprehension of experience (encoding stimuli), education of relations (inferring rules), and education of correlates (applying rules). Guilford's (1967) theory has clear process implications, in that one of the three facets in Guilford's structure-of-intellect cube isolates processes as factors. And in Jensen's (1970) theory, Level I intelligence can be understood in terms of the relatively simple kinds of associative learning studied by early S–R theorists, whereas Level II intelligence can be understood in terms of the more complex kinds of conceptual learning studied only by later S–R theorists (such as Gagne, 1970). In sum, then, the various units are compatible, not contradictory. They highlight different aspects of the global and ill-defined concept of intelligence. The emphasis in this chapter on the component as the unit of analysis reflects my view that the component is a particularly useful unit for understanding the nature and functioning of human intelligence.

The remainder of this chapter will be devoted to the elaboration of my own particular componential subtheory of human intelligence.¹ This subtheory is not necessarily representative of all theories of this kind, and it is still primitive in many respects. But unrepresentative and primitive as it may be, it is probably one of the more fully developed componential subtheories of intelligence. It thus suggests one direction in which this kind of theory can proceed. The subsequent discussion will be divided into four sections. The first will deal with properties of components, the second with kinds of components, the third with interrelations among kinds of components, and the fourth with how the subtheory accounts for various empirical findings in the literature on human intelligence.

A Componential Subtheory of Human Intelligence

Properties of Components

Each component has three important properties associated with it: duration, difficulty (that is, error probability), and probability of execution. Methods for estimating these properties of components are described in Sternberg (1978) (see also Sternberg, 1977, 1980b; Sternberg & Rifkin, 1979). The three properties are, at least in principle, independent. For example, a given component may take a rather long time to execute, but may be rather easy to execute, in the sense that its execution rarely leads to an error

¹Useful recent reviews of other componential types of theories can be found in Carroll and Maxwell (1979), Pellegrino and Glaser (1979), Snow (1979), and Sternberg (1979b). The heavy emphasis on "metacomponential" functioning that characterizes my own perspective is consistent with and has been influenced by such metacognitive (but not necessarily componential) theorists as Brown (1978; Brown & DeLoache, 1978; Campione & Brown, 1979) and Flavell (Flavell & Wellman, 1977).

in the solution; or the component may be executed quite rapidly, and yet be rather difficult to execute, in the sense that its execution often leads to an error in the solution (see Sternberg, 1977, 1980b). Consider “mapping,” one component used in solving analogies such as LAWYER is to CLIENT as DOCTOR is to (a) PATIENT or (b) MEDICINE. Mapping calls for the discovery of the higher-order relation between the first and second halves of the analogy. The component has a certain probability of being executed in solving an analogy. If executed, it has a certain duration and a certain probability of being executed correctly (Sternberg, 1977).

Kinds of Components

Components can be classified by function and by level of generality.

Function

Components perform (at least) five kinds of functions. *Metacomponents* are higher-order control processes used for executive planning and decision making in problem solving. *Performance components* are processes used in the execution of a problem-solving strategy. *Acquisition components* are processes used in learning new information. *Retention components* are processes used in retrieving previously stored knowledge. *Transfer components* are processes used in generalization, that is, in carrying over knowledge from one task or task context to another.

Metacomponents

Metacomponents² are specific realizations of control processes that are sometimes collectively (and loosely) referred to as the “executive” or the “homunculus.” I have identified six metacomponents that I believe are quite common in intellectual functioning.

1. *Decision as to just what the problem is that needs to be solved.* Anyone who has done research with young children knows that half the battle is getting them to understand what is being asked of them. Their difficulty often lies not in actually solving a problem, but in figuring out just what the problem is that needs to be solved (see, for example, Flavell, 1977; Sternberg & Rifkin, 1979). A major feature distinguishing retarded persons from normal ones is the retardates’ need to be instructed explicitly and completely as to the nature of the particular task he or she is solving and how it should be performed (Butterfield, Wambold, & Belmont, 1973; Campione & Brown, 1977, 1979). The importance of figuring out the nature of the problem is not limited to children and retarded persons. Resnick and Glaser (1976) have argued that intelligence is the ability to learn in the absence of direct or complete instruction. Indeed, distractors on intelligence tests are frequently chosen so as to be the right answers to the wrong problems. In my own research, I have found that the sheer novelty of a task, defined in terms of subjects’ unfamiliarity with what they are being asked to do, is an important determinant of the task’s correlation with measured intelligence (Sternberg, 1981b).

²Research on the isolation of metacomponents from task performance is being pursued in collaboration with Bill Salter, and is summarized in Sternberg (1979d).

2. *Selection of lower-order components.* An individual must select a set of lower-order (performance, acquisition, retention, or transfer) components to use in the solution of a given task. Selecting a nonoptimal set of components can result in incorrect or inefficient task performance. In some instances, the choice of components will be partially attributable to differential availability or accessibility of various components. For example, young children may lack certain components that are necessary or desirable for the accomplishment of particular tasks, or they may not yet execute these components in a way that is efficient enough to facilitate task solution. Sternberg and Rifkin (1979), for example, tested children in grades 2, 4, and 6, as well as adults, in their abilities to solve simple analogy problems. They found that the performance component used to form the higher-order relation between the two halves of the analogy (mapping) was used by adults and by children in the fourth and sixth grades. The authors suggested that the second graders might not yet have acquired the capacity to discern higher-order relations (that is, relations between relations). The unavailability or inaccessibility of this mapping component necessitated a rather radical shift in the way the youngest children solved the analogy problems. Sometimes the failure to execute the components needed for solving a task can be traced to a deficiency in the knowledge necessary for the execution of those components. Sternberg (1979a), for example, found that failures in reasoning with logical connectives were due, for the most part, to incorrect encodings of these connectives. Had the meanings of these connectives been available to the subjects (and especially the younger ones), the components of reasoning might well have been correctly executed.

3. *Selection of one or more representations or organizations for information.* A given component can often operate on any one of a number of different possible representations or organizations for information. The choice of representation or organization can facilitate or impede the efficacy with which the component operates. Sternberg and Rifkin (1979), for example, found that second graders organized information about analogies differently from older children and adults, but that this idiosyncratic organization enabled them to solve the analogies in a way that compensated for limitations in their working memories and mapping abilities. Sternberg and Weil (1980) found that the efficacy of various representations for information (linguistic, spatial, linguistic and spatial) in the linear-syllogisms task (for example, John is taller than Bill; Bill is taller than Peter; who is tallest?) depended upon individual subjects' patterns of verbal and spatial abilities. In problem solving, the optimal form of representation for information may depend upon item content. In some cases (for example, geometric analogies), an attribute-value representation may be best. In other cases (for example, animal-name analogies), a spatial representation may be best (Sternberg & Gardner, 1979). Thus, the efficacy of a form of representation can be determined by either subject variables or task variables, or by the interaction between them.

4. *Selection of a strategy for combining lower-order components.* In itself, a list of components is insufficient to perform a task. One must also sequence these components in a way that facilitates task performance, decide how exhaustively each component will be used, and decide which components to execute serially and which to execute in parallel. In an analogies task, for example, alternative strategies for problem solving differ in terms of which components are exhaustive and which are self-terminating. The exhaustively executed components result in the comparison of all possible encoded attributes or dimensions linking a pair of terms (such as LAWYER and CLIENT, or DOCTOR and PATIENT). The components executed with self-termination result in the comparison of only a subset of the attributes that have been encoded. The individual

must decide which comparisons are to be done exhaustively, and which are to be done with self-termination (Sternberg, 1977). An incorrect decision can drastically affect performance. Overuse of self-terminating components can result in a considerable increase in error (Sternberg, 1977; Sternberg & Rifkin, 1979). Overuse of exhaustive components can result in a considerable increase in solution latency (Sternberg, Ketron, & Powell, 1982).

5. *Decision regarding speed–accuracy tradeoff.* All tasks and components used in performing tasks can be allotted only limited amounts of time, and greater restrictions on the time allotted to a given task or task component may result in a reduction in the quality of performance. One must therefore decide how much time to allot to each component of a task, and how much the time restriction will affect the quality of performance for that particular component. One tries to allot time across the various components of task performance in a way that maximizes the quality of the entire product. Even small changes in error rate can result in sizable changes in solution latency (Pachella, 1974). I have found in the linear-syllogisms task, for example, that a decrease in solution latency of just one second (from a mean of about seven seconds to a mean of about six seconds) results in a seven-fold increase in error rate (from about 1% to about 7%; Sternberg, 1980a).

6. *Solution monitoring.* As individuals proceed through a problem, they must keep track of what they have already done, what they are currently doing, and what they still need to do. The relative importance of these three items of information differs across problems. If things are not progressing as expected, an accounting of one's progress may be needed, and one may even have to consider the possibility of changing goals. Often, new, more realistic goals need to be formulated as a person realizes that the old goals cannot be reached. In solving problems, individuals sometimes find that none of the available options provides a satisfactory answer. The individual must then decide whether to reperform certain processes that might have been performed erroneously, or to choose the best of the available answers (Sternberg, 1977). In the solution of linear syllogisms, the best strategy for most subjects is a rather nonobvious one, and hence subjects not trained in this strategy are unlikely to realize its existence until they have had at least some experience solving such problems (Quinton & Fellows, 1975; Sternberg & Weil, 1980).

A full discussion of methods for isolating metacomponents from composite task performance is outside the scope of this chapter (but see Sternberg, 1979d). Generally, metacomponents cannot be isolated on the basis of performance in standard information-processing paradigms, because latencies of higher-order planning and decision operations are usually constant across item types. As a result, metacomponential latencies are confounded with the constant response component or regression intercept. This confounding, in turn, can result in the seemingly inexplicable correlation of the response constant with scores on tests of intelligence (Hunt, Lunneborg, & Lewis, 1975; Pellegrino & Glaser, 1980; Sternberg, 1977, 1979c). One or more metacomponents can be isolated if planning and decision times are manipulated. We have developed paradigms in which items vary in the amount of strategy planning they require, and these paradigms have enabled us to extract metacomponential latencies from latencies for standard performance components (Sternberg, 1979d; Sternberg & Salter, 1980). For example, an analogy of the form A is to B as C is to X (where a series of X represents multiple answer options) requires less strategy planning than an analogy of the form A is to X, as Y is to D, where both X and Y represent multiple

options. Strategy planning time and difficulty are manipulated by varying the number and placement of the variable terms.

Performance Components³

Performance components are used in the execution of various strategies for task performance. Although the number of possible performance components is quite large, many probably apply only to small or uninteresting subsets of tasks, and hence deserve little attention. As examples of performance components, consider some components that are quite broad in applicability, those used in analogical and other kinds of inductive reasoning and problem-solving tasks. Examples of other kinds of inductive reasoning tasks include classification and series completion problems (Sternberg, 1977; Sternberg & Gardner, 1979).

Encoding. In any problem-solving situation, a person must encode the terms of the problem, storing them in working memory and retrieving them from long-term memory information relating to these problem terms. Consider, for, example, the analogy cited earlier, LAWYER is to CLIENT as DOCTOR is to (a) PATIENT or (b) MEDICINE. From long-term memory the person must retrieve attributes of LAWYER such as “professional person,” “law-school graduate,” and “member of the bar,” and place these attributes in working memory.

Inference. In inference, a person detects one or more relations between two objects, both of which may be either concrete or abstract. In the analogy, the person detects relations between LAWYER and CLIENT, such as that a lawyer provides professional services to a client.

Mapping. In mapping, a person relates aspects of a previous situation to aspects of a present one. In an analogy, the person seeks the higher-order relationship between the first half of the analogy (the previous situation) and the second half of the analogy (the present situation). In the example, both halves of the analogy deal with professional persons.

Application. In application, individuals use the relations between past elements of the situation and the decision made about them in the past to help them make current decisions. In the example, the person seeks to find an option that is related to DOCTOR in the same way that CLIENT was related to LAWYER.

Justification. In justification, the individual seeks to verify the better or best of the available options. In the example, PATIENT may not be viewed as a perfect analogue to CLIENT, because a patient may be viewed as a type of client, but not vice versa; but PATIENT is clearly the better of the two options.

Response. In response, the person communicates a solution to the problem. In the present example, the person communicates selection of the option PATIENT.

Methods for isolating performance components in a large variety of reasoning and problem-solving tasks have been described elsewhere (Guyote & Sternberg, 1978;

³In most of my earlier writings, I referred to performance components simply as “components.”

Schustack & Sternberg, 1979; Sternberg, 1977, 1978, 1980b; Sternberg & Nigro, 1980; Sternberg & Rifkin, 1979). Similar methods have been used by others in a broad range of cognitive tasks (for example, Clark & Chase, 1972; Posner & Mitchell, 1967; Shepard & Metzler, 1971; S. Sternberg, 1969). These methods have in common their manipulation of stimulus characteristics such that each particular kind of manipulation results in prolonging the latency of one particular performance component. Taken together, the various manipulations permit the simultaneous isolation of multiple performance components, either through analysis of variance or multiple regression techniques.

Acquisition, Retention, and Transfer Components⁴

Acquisition components are skills involved in learning new information; retention components are skills involved in retrieving previously acquired information; transfer components are skills involved in generalizing retained information from one situational context to another. Our research has not yet enabled us to specify what these components are; at present, we are still trying to identify the variables that affect acquisition, retention, and transfer of information in real-world contexts. What are some of the variables that might be involved in these three aspects of information processing? I shall address this question in the context of a person's trying to acquire, retain, and transfer information about unfamiliar words embedded in familiar contexts, such as newspapers and magazines.

Number of Occurrences of Target Information. Certain aspects of a situation will recur in virtually every instance of that kind of situation; others will occur only rarely. Higher acquisition, retention, and transfer of information would be expected from those aspects that recur with greater regularity. In the example, the more times a new and originally unfamiliar word is seen, the more likely an able person is to, acquire, retain, or transfer its meaning.

Variability in Contexts for Presenting Target Information. Some kinds of information about a given kind of situation will be available in multiple contexts, whereas other kinds may be available only in single or very limited contexts. Higher acquisition, retention, and transfer of information would be expected from aspects of a situation that are presented in more variable contexts. For example, the more variable the contexts are in which a previously unfamiliar word is presented, the more likely one is to acquire, retain, or transfer the word's meaning.

Importance of Target Information to Overall Situation. Some kinds of information about a given kind of situation will be central to that situation and decisions made about it; other kinds will be peripheral, and will have only a minor impact on subsequent decisions. Higher acquisition, retention, and transfer of information would be expected from those aspects that are central to that kind of situation. For example, the more important the meaning of a previously unfamiliar word is to understanding the passage in which it occurs, the better the context is for acquiring, retaining, and transferring the word's meaning.

⁴Research on the identification and isolation of acquisition, retention, and transfer components in everyday reading is being pursued in collaboration with Janet Powell, and is summarized in Sternberg (1979d).

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Recency of Target Information. Certain information about a situation may have occurred more recently in one's experience, whereas other information may have occurred in the more distant past. Higher retention would be expected from those aspects of a kind of situation that have occurred in one's more recent experience. If, for example, a previously unfamiliar word has been recently encountered, one is more likely to retain its meaning.

Helpfulness of Context to Understanding Target Information. Certain kinds of information may be presented in contexts that facilitate their acquisition, retention, and transfer; other kinds may be presented in less facilitative contexts. Better acquisition, retention, and transfer would be expected when the context is more facilitating. For example, the more clues a new word's context provides as to its meaning, the more likely one is to acquire, retain, and transfer the word's meaning.

Helpfulness of Stored Information for Understanding Target Information. Previously stored information can facilitate acquisition, retention, and transfer of new information. Higher learning, retention, and transfer would be expected in cases where information learned in the past can be brought to bear on the present information, providing a context that may not be contained in the new learning situation itself. For example, if one recognizes a Latin root in an unfamiliar word, one is more likely to acquire, retain, and transfer the meaning of that word.

Because I have dealt only minimally with acquisition, retention, and transfer components in my previous writings, it may be useful if I describe in some detail the experimental paradigm we are using to isolate the effects of the variables believed to affect these components (see also Sternberg, 1979d). In our current research paradigm, we present subjects with a series of narrative passages of the kind found in newspapers, textbooks, magazines, and other everyday sources of information. The passages are typical in every respect except that they contain embedded within them one or more words of extremely low frequency in the English language. A given low-frequency word can occur one or more times within a given passage, or many times across passages. After reading each passage, subjects indicate what they believe to be the gist of the passage; they also define each of the low-frequency words. Structural variables in the narrative passages are used to predict the relative difficulties of learning, transferring, or retaining the various words. At the end of the experiment, subjects are again asked to define all the words, this time only in the context of the complete set of low-frequency words they have seen.

The first possible test of the meaning of a given word is at the end of the passage in which the word first occurs. At this time, the subject can look back at the passage to try to figure out what the word means. Results from this test are used to estimate the difficulty of acquisition variables. The second possible test of the meaning of a given word is at the end of a passage in which that word occurs for the second time in a second and new context. In this test, as in the preceding one, the subject is allowed to look back for help in defining the word in the passage that was just read. The subject is not allowed to look back at the preceding passage in which the word occurred, however. Improvement in the quality of this second definition relative to the quality of the first serves as the basis for estimating the difficulty of transfer variables. The same procedure applies to the third and fourth possible tests. The last possible test of the meaning of a given word is in the final definitions test. In this test, the only supporting context is provided by the other low-frequency words.

Subjects are not allowed to look back at the previous passages. Definition quality in this final test is used as the basis for estimating the difficulty of retention variables.

Level of Generality

Components can be classified in terms of three levels of generality. *General components* are required to perform all tasks within a given task universe; *class components* are required to perform a proper subset of tasks that includes at least two within the task universe; and *specific components* are required to perform single tasks within the task universe. Tasks calling for intelligent performance differ in the numbers of components they require for completion and in the number of each kind of component they require.

Consider, again, the example of an analogy. “Encoding” seems to be a general component, in that it is needed in the solution of problems of all kinds—a problem cannot be solved unless its terms are encoded in some manner. “Mapping” seems to be a class component, in that it is required for the solution of certain kinds of induction problems. But it is certainly not needed in problems of all kinds. No task-specific components have been identified in analogical reasoning, which is perhaps one reason why analogies serve so well in tests of general intellectual functioning.

Two points need to be emphasized with regard to the level of generality of components. First, whereas components with different functions are qualitatively different from each other, components at different levels of generality are not. Function inheres in a given component; level of generality inheres in the range of the tasks into which a given component enters. Second, whereas a given component serves only a single function, it may serve at any level of generality, with the level depending on the scope of the set of tasks being considered. A component may be general in a very narrow range of tasks, for example, but class-related in a very broad range of tasks. Levels of generality will prove useful in understanding certain task interrelationships and factorial findings; their primary purpose is to provide a convenient descriptive language that is useful for conceptualizing certain kinds of phenomena in componential terms.

Interrelations Among Kinds of Components

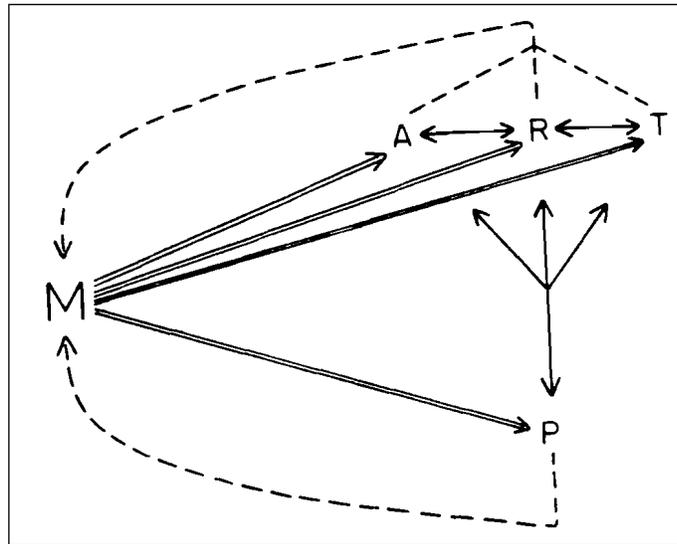
Components are interrelated in various ways. I shall discuss first how components serving different functions are interrelated, and then how components of different levels of generality are interrelated. Because levels of generality and functions are completely crossed, the interrelations among components of differing levels of generality apply to all of the functionally different kinds of components, and the interrelations among the functionally different kinds of components apply at all levels of generality.

Function

My speculations regarding the interrelations among the functionally different kinds of components are shown in Figure 1.1. The various kinds of components are closely related, as would be expected in an integrated, intelligent system. Four kinds of interrelations need to be considered: Direct activation of one kind of component by another is represented by double solid arrows. Indirect activation of one kind by another is represented by single solid arrows. Direct feedback from one kind to another

1.1

Interrelations among components serving different functions. In the figure, "M" refers to a set of metacomponents, "A" to a set of acquisition components, "R" to a set of retention components, "T" to a set of transfer components, and "P" to a set of performance components.



Direct activation of one kind of component by another is represented by solid double arrows. Indirect activation of one kind of component by another is represented by single solid arrows. Direct feedback from one kind of component to another is represented by single broken arrows. Indirect feedback from one kind of component to another proceeds from and to the same components as does indirect activation, and so is shown by the single solid arrows.

is represented by single broken arrows. Indirect feedback proceeds from and to the same components as does indirect activation, and so is shown by the single solid arrows. Direct activation or feedback refers to the immediate passage of control or information from one kind of component to another. Indirect activation or feedback refers to the mediated passage of control or information from one kind of component to another via a third kind of component.

In the proposed system, only metacomponents can directly activate and receive feedback from each other kind of component. Thus, all control passes directly from the metacomponents to the system, and all information passes directly from the system to the metacomponents. The other kinds of components can activate each other indirectly, and receive information from each other indirectly; in every case, mediation must be supplied by the metacomponents. For example, the acquisition of information affects the retention of information and various kinds of transformations (performances) on that information, but only via the link of the three kinds of components to the metacomponents. Information from the acquisition components is filtered to the other kinds of components through the metacomponents.

Consider some examples of how the system might function in the solution of a word puzzle, such as an anagram (scrambled word). As soon as one decides on a certain tentative strategy for unscrambling the letters of the word, activation of that strategy can pass directly from the metacomponent responsible for deciding on a strategy to the performance component responsible for executing the first step of

the strategy, and subsequently, activation can pass to the successive performance components needed to execute the strategy. Feedback will return from the performance components indicating how successful the strategy is turning out to be. If the monitoring of this feedback signals lack of success, control may pass to the metacomponent that is “empowered” to change strategy; if no successful change in strategy can be realized, the solution-monitoring metacomponent may change the goal altogether.

As a given strategy is being executed, new information is being acquired about how to solve anagrams in general. This information is also fed back to the metacomponents, which may act on or ignore this information. New information that seems useful is more likely to be directed back from the relevant metacomponents to the relevant retention components for retention in long-term memory. What is acquired does not directly influence what is retained, however, so that “practice does not necessarily make perfect.” Some people may be unable to profit from their experience because of inadequacies in metacomponential information processing. Similarly, what is retained does not directly influence what is later transferred. The chances of information being transferred to a later context will largely depend on the form in which the metacomponents have decided to store the information for later access. Acquired information also does not directly affect transformations (performances) on that information. The results of acquisition (or retention or transfer) must first be fed back into the metacomponents, which in effect decide what information will filter back indirectly from one type of component to another.

The metacomponents are able to process only a limited amount of information at a given time. In a difficult task, and especially a new and different one, the amount of information being fed back to the metacomponents may exceed their capacity to act on the information. In this case, the metacomponents become overloaded, and valuable information that cannot be processed may simply be wasted. The total information-handling capacity of the metacomponents of a given system will thus be an important limiting aspect of that system. Similarly, the capacity to allocate attentional resources so as to minimize the probability of bottlenecks will be part of what determines the effective capacity of the system (see also Hunt et al., 1973, 1975).

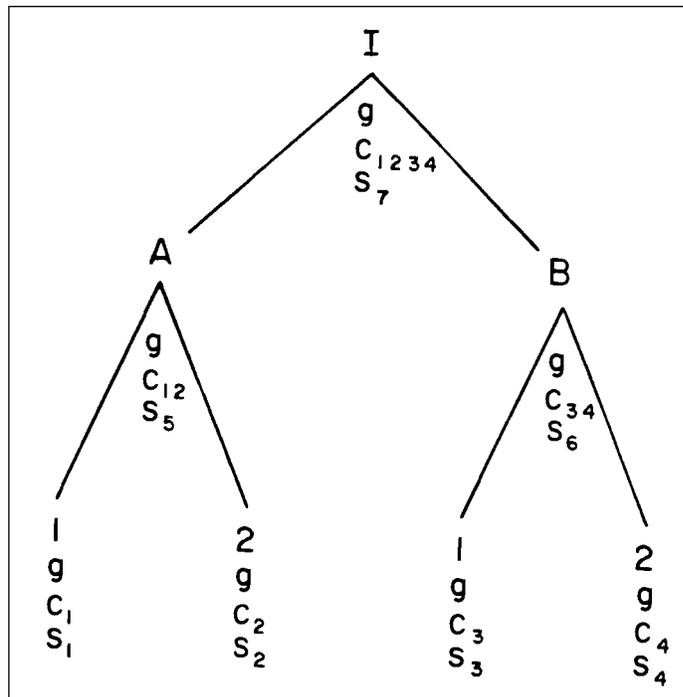
Figure 1.1 does not show interrelations among various individual members of each single functional kind of component. These interrelations can be easily described in words, however. Metacomponents are able to communicate with each other directly, and to activate each other directly. It seems likely that there exists at least one metacomponent (other than those described earlier in the chapter) that controls communication and activation among the other metacomponents, and there is a certain sense in which this particular metacomponent might be viewed as a “meta-metacomponent.” Other kinds of components are not able to communicate directly with each other, however, or to activate each other. But components of a given kind can communicate indirectly with other components of the same kind, and can activate them indirectly. Indirect communication and activation proceed through the metacomponents, which can direct information or activation from one component to another of the same kind.

Level of Generality

Components of varying levels of generality are related to each other through the ways in which they enter into the performance of tasks (Sternberg, 1979c, 1980c). Figure 1.2 shows the nature of this hierarchical relationship. Each node of the hierarchy contains a task, which is designated by a roman or arabic numeral or by a letter. Each

1.2

Interrelations among components of different levels of generality. Each node of the hierarchy contains a task, which is designated by a roman or arabic numeral or by a letter. Each task comprises a set of components at the general (g), class (c), and specific (s) levels. In the figure, "g" refers



to a set of general components; "c_i" and "c_j" each refer to a set of class components, and "c_{ij}" refers to a concatenated set of class components that includes the class components from both c_i and c_j; "s_i" refers to a set of specific components.

task comprises a set of components at the general (g), class (c), and specific (s) levels. In the figure, "g" refers to a set of general components; "c_i" and "c_j" each refer to a set of class components, whereas "c_{ij}" refers to a concatenated set of class components that includes the class components from both c_i and c_j, and "s_i" refers to a set of specific components. The levels of the hierarchy differ in terms of the complexity of the tasks assigned to them. More complex tasks occupy higher levels of the hierarchy; simpler tasks occupy lower levels. Relative complexity is defined here in terms of the number and identities of the class components contained in the task: the more sets of class components concatenated in a particular task, the more complex the task is.

At the bottom of the hierarchy are very simple tasks (IA1, IA2, IB1, IB2), each of which requires a set of general, class and specific components for its execution. At one extreme, the general components are the same in all four tasks (and in all of the tasks in the hierarchy), in that a general component is by definition one that is involved in the performance of every task in the universe (here expressed as a hierarchy) of interest. At the other extreme, the specific components are unique to each task at this (and every other) level, in that a specific component is by definition one that is only relevant to a single task. The class components are also not shared across tasks at this level: Task IA1 has one set of class components; Task IA2 another; Task IB1 another; and Task IB2 yet another. As examples, Task IA1 might be series completions (such as 2, 4, 6, 8, ?), Task IA2 metaphorical ratings (How good a metaphor is "The moon

is a ghostly galleon?”), Task IB1 linear syllogisms (N is higher than P; P is higher than L; which is highest?), and Task IB2 categorical syllogisms (All C are B; some B are A; can one conclude that some C are A?) (see Sternberg, 1980c).

Consider next the middle level of the hierarchy, containing Tasks IA and IB. Tasks IA and IB both share with the lower-order tasks, and with each other, all of their general components but none of their specific components. What distinguishes Tasks IA and IB from each other, however, and what places them in their respective positions in the hierarchy, is the particular set of class components that they each contain. The class components involved in the performance of Task IA represent a concatenation of the class components involved in the performance of Tasks IA1 and IA2; the class components involved in the performance of Task IB represent a concatenation of the class components involved in the performance of Tasks IB1 and IB2. Tasks IA and IB contain no common class components, however. For example, Task IA might be analogies, which require a concatenation of the class components from series completions and metaphorical ratings. Task IB might be the higher-order task of quantified linear syllogisms (for example, all H are higher than all Q; some Q are higher than all Z; can one conclude that some H are higher than some Z?), which requires a concatenation of class components from linear and categorical syllogisms (see Sternberg, 1980c).

Finally, consider the task at the top level of the hierarchy, Task I. Like all tasks in the hierarchy, it shares general components with all other tasks in the hierarchy, but it shares specific components with none of these tasks (again, because these components are, by definition, task-specific). Performance on this task is related to performance on Tasks IA and IB through the concatenation of class components from these two tasks. In the present example, Task I might be inductive syllogisms, which require a person to induce the premises of a syllogism and then to solve the syllogism. Scientific reasoning is often of this kind: one must induce regularities from empirical data, and then deduce properties of these regularities (see Sternberg, 1980e).

According to the present view, many kinds of tasks are hierarchically interrelated to each other via components of information processing. The proposed hierarchical model shows the nature of these interrelations. It should be made clear just what is arbitrary in this hierarchical arrangement and what is not. The arrangement does not prespecify the degrees of differentiation between the top and bottom levels of the hierarchy, nor where the hierarchy should start and stop. As was stated earlier, the level that is defined as “elementary” and thus suitable for specification of components is arbitrary: what is a component in one theory might be two components in another, or a task in still another. The level of specification depends on the purpose of the theory. Theories at different levels serve different purposes, and must be justified in their own right. But certain important aspects of the arrangement are not arbitrary. The vertical order of tasks in the hierarchy, for example, is not subject to permutation, and although whole branches of the hierarchy (from top to bottom) can be permuted (the left side becoming the right side and vice versa), individual portions of those branches cannot be permuted. For example, IA and IB cannot be switched unless the tasks below them are switched as well. In other words, horizontal reflection of the whole hierarchy is possible, but horizontal reflection of selected vertical portions is not possible. These nonarbitrary elements of the hierarchy make disconfirmation of a given theory both possible and feasible. A given hierarchy can be found to be inadequate if the various constraints outlined here are not met. In many instances,

the hierarchy may simply be found to be incomplete, in that branches or nodes of branches may be missing and thus need to be filled in.

The interrelational schemes described above are intended to provide a framework for explaining empirical phenomena, rather than to provide an actual explanation. This framework will be used below to provide a unified perspective for understanding empirical findings in the literature on intelligence.

Relations Between Components and Human Intelligence

On the componential view, components account causally for a part of what we consider to be human intelligence. If one takes a broad view of general intelligence as capturing those aspects of behavior that contribute to the effectiveness of adaptation to everyday living, there will certainly be major parts of intelligence that are not accounted for within the componential framework. Nevertheless, components are perhaps able to account at one level for an interesting portion of what we call "intelligent behavior." Consider some of the key phenomena described in the textbook literature on intelligence (for example, Brody & Brody, 1976; Butcher, 1970; Cronbach, 1970; Vernon, 1979), and how they would be explained within the componential framework. Some of these phenomena have actually appeared to be mutually incompatible, but no longer appear so when viewed through the "lens" of the componential framework. None of these phenomena has been established beyond a doubt; indeed, some of them are subject to considerable controversy. Nevertheless, they are about as solid as any phenomena reported in the literature on intelligence, and they are ones I, at least, am willing to accept tentatively until the evidence sways me to believe otherwise.

1. *There appears to be a factor of "general intelligence."* Various sorts of evidence have been adduced in support of the existence of a general intelligence factor (see Humphreys, 1979; McNemar, 1964). Perhaps the most persuasive evidence is everyday experience: Casual observation in everyday life suggests that some people are "generally" more intelligent than others. People's rank orderings of each other may differ according to how they define intelligence, but some rank ordering is usually possible. Historically, the evidence that has been offered most often in favor of the existence of general intelligence is the appearance of a general factor in unrotated factor solutions from factor analyses of tests of intelligence (for example, Spearman, 1927). In itself, this evidence is not persuasive, because factor analysis of any battery of measures will yield a general factor if the factors are not rotated: This is a mathematical rather than a psychological outcome of factor analysis. However, the psychological status of this outcome is bolstered by the fact that an analogous outcome appears in information-processing research as well: Information-processing analyses of a variety of tasks have revealed that the "regression constant" is often the individual-differences parameter most highly correlated with scores on general intelligence tests (see Sternberg, 1979c). This parameter measures what is constant across all of the item or task manipulations that are analyzed via multiple regression. The regression constant seems to have at least some parallels with the general factor.

The strongest evidence that has been offered against the existence of general intelligence is that some rotations of factors fail to yield a general factor. But this failure to find a general factor in certain kinds of rotated solutions is as much determined by mathematical properties of the factorial algorithm as is the success in finding a general

factor in an unrotated solution. Moreover, if the multiple factors are correlated, and if they are themselves factored, they will often yield a “second-order” general factor.

In componential analysis, individual differences in general intelligence are attributed to individual differences in the effectiveness with which general components are used. Because these components are common to all of the tasks in a given task universe, factor analyses will tend to lump these general sources of individual-difference variance into a single general factor. As it happens, the metacomponents have a much higher proportion of general components among them than do any of the other kinds of components, presumably because the executive routines needed to plan, monitor, and possibly replan performance are highly overlapping across widely differing tasks. Thus, individual differences in metacomponential functioning are largely responsible for the persistent appearance of a general factor.

Metacomponents are probably not solely responsible for “g,” however. Most behavior, and probably all of the behavior exhibited on intelligence tests, is learned. Certain acquisition components may be general to a wide variety of learning situations, which also enter into the general factor. Similarly, components of retention and transfer may also be common to large numbers of tasks. Finally, certain aspects of performance—such as encoding and response—are common to virtually all tasks, and they, too, may enter into the general factor. Therefore, although the metacomponents are primarily responsible for individual differences in general intelligence, they are probably not solely responsible.

2. *Intelligence comprises a set of “primary mental abilities.”* When a factorial solution is rotated to a Thurstonian (1947) “simple structure,” a set of primary mental abilities usually appears. The concept of simple structure is complexly defined, but basically involves a factorial solution in which factors tend to have some variables loading highly on them, some variables loading only modestly on them, and few variables having intermediate loadings on them. As noted previously, the appearance of one or another kind of factor set is largely a mathematical property of factor analysis and the kind of rotation used (see also Sternberg, 1977). If one views factors as causal entities, as do many adherents to the traditional psychometric approach to intelligence, then one may become involved in a seemingly unresolvable debate regarding which is the “correct” rotation of factors. Mathematically, all rigid rotations of a set of factor axes are permissible, and there seems to be no agreed-upon psychological criterion for choosing a “correct” rotation. In componential analysis, the choice of a criterion for rotation is arbitrary—a matter of convenience. Different rotations serve different purposes. The unrotated solution considered earlier, for example, is probably ideal for isolating a composite measure of individual differences in the effectiveness of the performance of general components.

Consider next what is probably the most popular orientation of factorial axes among American psychometricians, that obtained by Thurstonian rotation to simple structure. In such rotations, primary mental abilities such as verbal comprehension, word fluency, number, spatial visualization, perceptual speed, memory, and reasoning may appear (see Thurstone, 1938). The simple-structure rotation, like the unrotated solution, has somehow seemed special to psychometricians for many years, and I believe that it may well be, in a sense, special. Whereas the unrotated solution seems to provide the best composite measure of general components, my inspections of various rotated solutions have led me to believe that simple-structure rotations tend to provide the “best” measures of class components—best in the sense that there is

minimal overlap across factors in the appearances of class components. A simple-structure rotation distributes the general components throughout the set of factors so that the same general components may appear in multiple factors: Such factors, therefore, will necessarily be correlated. But I believe the low to moderate correlations are due for the most part to overlap among general components: The class components found at a fairly high level of generality seem to be rather well restricted to individual factors. Given that the factorial model of primary mental abilities originally proposed by Thurstone was nonhierarchical, there will have to be some overlap across factors in class components; but for theoretical and practical purposes, this overlap seems to be minimized. Thus, neither the unrotated solution of Spearman (1927) and others, nor the simple-structure solution of Thurstone (1938) and others, is “correct” to the exclusion of the other. Each serves a different theoretical purpose and possibly a different practical purpose as well: The factorial theory of Spearman is useful when one desires the most general, all-purpose predictor possible; the factorial theory of Thurstone is useful when one desires differential prediction, for example, between verbal and spatial performance.

3. *In hierarchical factor analyses, there seem to be two very broad group factors (or general subfactors), sometimes referred to as crystallized ability and fluid ability.* The crystallized-fluid distinction has been proposed by Cattell (1971) and Horn (1968), and a similar distinction has been proposed by Vernon (1971). Crystallized ability is best measured by tests that measure the products of enculturation: vocabulary, reading comprehension, general information, and the like. Fluid ability is best measured by tests of abstract reasoning: abstract analogies, classifications, series completions, and the like. (Verbal items are also useful for this purpose if their vocabulary level is kept low.) Once again, I believe that there is something special about this hierarchical solution. Crystallized ability tests seem best able to separate the products of acquisition, retention, and transfer components. I say “products,” because crystallized ability tests measure outcomes of these component processes, rather than the operations as they are actually executed. The vocabulary that is measured by a vocabulary test, for example, may have been acquired years ago. Fluid ability tests, on the other hand, seem most suitable for separating the execution of performance components. These tests seem heavily dependent on a rather small set of performance components (Sternberg, 1979c; Sternberg & Gardner, 1979), in particular, those mentioned earlier in this chapter. Thus, dividing factors along the crystallized-fluid dimension seems to provide a good distinction between the products of acquisition, retention, and transfer components on the one hand, and the current functioning of performance components on the other. Crystallized and fluid factors will be correlated, however, because of shared metacomponents.

Horn (1968) has found that crystallized ability generally continues to increase throughout one’s lifetime, whereas fluid ability first increases, then levels off, and finally decreases. I would like to suggest that the contrast between the continued increase in crystallized ability with age and the increase followed by decrease in fluid ability with increasing age is due less to the kinds of abilities measured than to the ways in which they are measured. Crystallized ability tests primarily measure accumulated products of components; fluid ability tests primarily measure current functioning of components. I think it likely that current functioning decreases after a certain age level, whereas the accumulated products of these components are likely to continue to increase (at least until senility sets in). Were one to measure current functioning of acquisition, retention, and transfer components—by, for example, tests

of acquisition of knowledge presented in context—rather than the products of these components, I suspect the ability curve would show a pattern of rise and fall similar to that shown on standard fluid ability tests.

4. *Procrustean rotation of a factorial solution can result in the appearance of a large number of “structure-of-intellect” factors.* Procrustean rotation of a factorial solution involves rotation of a set of axes into maximum correspondence with a predetermined theory regarding where the axes should be placed. Guilford (1967; Guilford & Hoepfner, 1971) has used procrustean rotation to support his “structure-of-intellect” theory. According to this theory, intelligence comprises 120 distinct intellectual aptitudes, each represented by an independent factor. Horn and Knapp (1973) have shown that comparable levels of support can be obtained via procrustean rotation to randomly determined theories. The viability of Guilford’s theory is therefore open to at least some question (see also Cronbach & Snow, 1977). Nevertheless, I believe that there is probably a psychological basis for at least some aspects of Guilford’s theory, and that these aspects of the theory can be interpreted in componential terms.

A given component must act on a particular form of representation for information, and on a particular type of information (content). The representation, for example, might be spatial or linguistic; the type of information (content) might be, for example, an abstract geometric design, a picture, a symbol, or a word. Forms of representations and contents, like components, can serve as sources of individual differences: A given individual might be quite competent when applying a particular component to one kind of content, but not when applying it to another. Representation, content, and process have been largely confounded in most factorial theories, probably because certain components tend more often to operate on certain kinds of representations and contents, and other components tend more often to operate on different kinds of representations and contents. This confounding serves a practical purpose, that of keeping to a manageable number the factors appearing in a given theory or test. But it does obscure the probably partially separable effects of process, representation, and content. Guilford’s theory provides some separation, at least between process and content. I doubt the product dimension has much validity, other than through the fact that different kinds of products probably involve slightly different mixes of components. On the one hand, the theory points out the potential separability of process and content. On the other hand, it does so at the expense of manageability. Moreover, it seems highly unlikely that the 120 factors are independent, as they will, at a minimum, share metacomponents.

The distinction among process, content, and representation is an important one to keep in mind, because it is in part responsible for the low intercorrelations that are often obtained between seemingly highly related tasks. Two tasks (such as verbal analogies and geometric analogies) may share the same information-processing components, and yet show only moderate correlations because of content and representational differences. Guilford’s finding of generally low intercorrelations between ability tests is probably due in part to the wide variation in the processes, contents, and representations required for solution of his various test items.

5. *One of the best single measures of overall intelligence (as measured by intelligence tests) is vocabulary.* This result (see, for example, Matarazzo, 1972) has seemed rather surprising to some, because vocabulary tests seem to measure acquired knowledge rather than intelligent functioning. But the preceding discussion should adumbrate why vocabulary is such a good measure of overall intelligence. Vocabulary is acquired incidentally throughout one’s life as a result of acquisition components; the vocabulary

that is retained long enough to be of use on a vocabulary test has also been successfully processed by a set of retention components. And for the vocabulary to be retained and recognized in the particular context of the vocabulary test, it probably also had to be processed successfully by transfer components. Moreover, to operate effectively, all these kinds of components must have been under the control of metacomponents. Thus, vocabulary provides a very good, although indirect, measure of the lifetime operations of these various kinds of components. Vocabulary has an advantage over many kinds of performance tests, which measure the functioning of performance components only at the time of testing. The latter kinds of tests are more susceptible to the day-to-day fluctuations in performance that create unreliability and, ultimately, invalidity in tests. Because performance components are not particularly critical to individual differences in scores on vocabulary tests, one would expect vocabulary test scores to be less highly correlated with performance types of tests than with other verbal tests, and this is in fact the case (see Matarazzo, 1972).

It was noted earlier that in some instances lack of knowledge can block successful execution of the performance components needed for intelligent functioning. For example, it is impossible to reason with logical connectives if one does not know what they mean (Sternberg, 1979a), or to solve verbal analogies if the meanings of words constituting the analogies are unknown. Thus, vocabulary is not only affected by operations of components, it affects their operations as well. If one grows up in a household that encourages exposure to words (which is one of the variables cited earlier as affecting acquisition, transfer, and retention components), then one's vocabulary may well be greater, which in turn may lead to superior learning and performance on other kinds of tasks that require vocabulary. This is one way in which early rearing can have a substantial effect on vocabulary and the behaviors it affects.

This view of the nature of vocabulary tests in particular, and of tests of verbal ability in general, differs from that of Hunt, Lunneborg, and Lewis (1975). These authors have sought to understand individual differences in verbal ability in terms of individual differences in performance components involved in relatively simple information-processing tasks used in laboratories of experimental psychologists. They suggest, for example, that a major element of verbal ability is the speed of accessing simple verbal codes in short-term memory. This framework is not incompatible with that presented here: The two views may highlight different aspects of verbal comprehension.

6. *The absolute level of intelligence in children increases with age.* Why do children grow smarter as they grow older? The system of interrelations among components depicted in Figure 1.1 seems to contain a dynamic mechanism whereby cognitive growth can occur.

First, the components of acquisition, retention, and transfer provide the mechanisms for a steadily developing knowledge base. Increments in the knowledge base, in turn, allow for more sophisticated forms of acquisition, retention, and transfer, and possibly for greater ease in executing performance components. For example, some transfer components may act by relating new knowledge to old knowledge. As the base of old knowledge becomes deeper and broader, the possibilities for relating new knowledge to old knowledge, and thus for incorporating that new knowledge into the existing knowledge base, increase. There is thus the possibility of an unending feedback loop: The components lead to an increased knowledge base, which leads to more effective use of the components, which leads to further increases in the knowledge base, and so on.

Second, the self-monitoring metacomponents can, in effect, learn from their own mistakes. Early on, allocation of metacomponential resources to varying tasks or kinds of components may be less than optimal, with a resulting loss of valuable feedback information. Self-monitoring should eventually result in improved allocations of metacomponential resources, in particular, to the self-monitoring of the metacomponents. Thus, self-monitoring by the metacomponents results in improved allocation of metacomponential resources to the self-monitoring of the metacomponents, which in turn leads to improved self-monitoring, and so on. Here, too, there exists the possibility of an unending feedback loop, one that is internal to the metacomponents themselves.

Finally, indirect feedback from components other than metacomponents to each other, and direct feedback to the metacomponents, should result in improved effectiveness of performance. Acquisition components, for example, can provide valuable information to performance components (via the metacomponents) concerning how to perform a task, and the performance components, in turn, can provide feedback to the acquisition components (via the metacomponents) concerning what else needs to be learned to perform the task optimally. Thus, other kinds of components, too, can generate unending feedback loops in which performance improves as a result of interactions between different kinds of components, or between multiple components of the same kind.

There can be no doubt that the major variables in the individual-differences equation will be those deriving from the metacomponents. All feedback is filtered through those elements, and if they do not perform their function well, then it won't matter very much what the other kinds of components can do. It is for this reason that the metacomponents are viewed as truly central in understanding the nature of general intelligence.

7. Intelligence tests provide imperfect, but quite good, prediction of academic achievement.

A good intelligence test such as the Stanford-Binet will sample widely from the range of intellectual tasks that can reasonably be used in a testing situation. The wider this sampling, and the more closely the particular mix of components sampled resembles the mix of components required in academic achievement, the better the prediction will be. A vocabulary test, for example, will provide quite a good predictor of academic achievement, because academic achievement is so strongly dependent on acquisition, transfer, and retention components, and on the metacomponents that control them. A spatial test will probably not be as good a predictor of general academic performance, because the performance components sampled in such a test will not be particularly relevant to general academic achievement, such as that required in English or history courses. An abstract reasoning test will probably be better than a spatial test, because the particular performance components involved in these tasks seem to be so general across tasks requiring inductive reasoning, including those found in academic learning environments. All intelligence tests will necessarily be imperfect predictors of academic achievement, however, because there is more to intelligence than is measured by intelligence tests, and because there is more to school achievement than intelligence.

8. Occasionally, people are quite good at one aspect of intellectual functioning, but quite poor at another. Everyone knows of people who exhibit unusual and sometimes bizarre discrepancies in intellectual functioning. A person who is mathematically gifted may have trouble writing a sentence, or an accomplished novelist may have trouble adding simple columns of numbers. In the componential framework, the discrepancy can be accounted for in either of two ways. First, there may be inadequate functioning of or inadequate feedback from particular class components. The discrepancy cannot be in

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the general components, because they are common to all tasks, nor can it be in the specific components, because they apply only to single tasks. Hence, the discrepancy must be found in those class components that permeate performance of a given set of tasks, such as mathematical tasks, verbal tasks, spatial tasks, or any of the other tasks that constitute measures of the "primary mental abilities." Note that in contrast, someone whose intellectual performance is generally depressed is more likely to be suffering from inadequacies in the execution of or feedback from general components (and possibly, class components as well). Second, the discrepancy can be accounted for by difficulty in operating on a particular form of representation. Different kinds of information are probably represented in different ways, at least at some level of information processing. For example, there is good reason to believe that linguistic and spatial representations differ in at least some respects from each other (MacLeod, Hunt, & Mathews, 1978; Paivio, 1971; Sternberg, 1980b). A given component may operate successfully upon one form of representation but not on another, as discussed earlier.

9. *Intelligence is a necessary but not sufficient condition for creativity.* Creativity, on the componential view, is due largely to the occurrence of transfer between items of knowledge (facts or ideas) that are not related to each other in an obvious way. In terms of the conceptualization in Figure 1.1, creative ideas derive from extremely sensitive feedback to and from transfer components. Such feedback is more likely to occur if, in acquisition, knowledge has been organized in a serviceable and richly interconnected way. But for interesting creative behavior to occur, there must be a rather substantial knowledge base so that there is something to and from which transfer can occur. Thus, for creativity to be shown, a high level of functioning in the acquisition, retention, and transfer components would seem necessary. These high levels of functioning are not in themselves sufficient for creativity to occur, however, because a sophisticated knowledge base does not in itself guarantee that the knowledge base will be used in sophisticated feedback to and from the transfer components. This mechanism is not intended to account for all creative behavior, nor even to give a full account of the creative behavior to which it can be applied. It does seem a start toward a more detailed account, however.

This componential view is consistent with recent research on expert-novice distinctions that suggests that a major part of what distinguishes experts from novices is differences in the knowledge base and its organization (for example, Chase & Simon, 1973; Glaser & Chi, 1979; Larkin, 1979). The view is also consistent with that of Horn (1980), who has suggested that creativity may be better understood by investigating crystallized ability rather than fluid ability. Our previous failures to isolate loci of creative behavior may derive from our almost exclusive emphasis on fluid abilities. The creativity tests that have resulted from this emphasis have measured what I believe to be rather trivial forms of creativity having little in common with the forms shown by creative novelists, artists, scientists, and the like. Research on transfer may be more productive.

10. *Speed and accuracy (or quality) of intelligent performance may be positively correlated, negatively correlated, or uncorrelated.* The results of the "new wave" of intelligence research (for example, Hunt et al., 1975; Mulholland, Pellegrino, & Glaser, 1980; Sternberg, 1977) make it clear that speed and quality of performance bear no unique relation to each other. In the analogies task, for example, faster inference, mapping, application, and response component times are associated with higher intelligence test scores, but slower encoding is also associated with higher test scores. This finding

can be understood at a metacomponential level: Individuals who encode stimuli more slowly are later able to operate on their encodings more rapidly and accurately than are individuals who encode stimuli more rapidly. Faster encoding can thus actually slow down and impair the quality of overall performance (Sternberg, 1979c). Similarly, individuals with higher intelligence tend to spend more time implementing the planning metacomponent, so as to spend less time in executing the performance components whose execution needs to be planned (Sternberg & Salter, 1980).

Findings such as these emphasize the importance of decomposing overall response time and response accuracy into their constituent components, as different components may show different relations with intelligent performance. These findings also show the importance of seeking explanations for behavior at the metacomponential level. As important as it is to know what individuals are doing, it is even more important to know why they are doing it.

11. *Training of intelligent performance is most successful when it is at both the metacomponential and performance-componential levels.* Research on the training of intelligent performance has shown that the most successful approach addresses metacomponential or metacognitive as well as specific performance components or strategies (Borkowski & Cavanaugh, 1979; Brown & DeLoache, 1978; Butterfield & Belmont, 1977; Feuerstein, 1979a, 1979b; Sternberg, 1981a). This finding is consistent with the kind of framework proposed in Figure 1.1. The interaction of metacomponents and performance components is such that training of just the one or the other kind of component will be fruitless unless there is at least some spillover into the other kind. The two kinds of components work in tandem, and hence are most successfully trained in tandem. To obtain generalizability as well as durability of training, it may also be necessary to train transfer components.

12. *Intelligence can mean somewhat different things in different cultures.* Cross-cultural research suggests that intelligence can mean somewhat different things in different cultures (Berry, 1974; Cole, Gay, Glick, & Sharp, 1971; Goodnow, 1976; Wober, 1974; see also Neisser, 1976, 1979). This view is consistent with the componential framework presented here. I interpret the available evidence as providing no support for the notion that the components of human intelligence or the ways in which these components are organized differ across cultures; but the evidence provides considerable support for the notion that the relative importance of the various components differs across cultures, as does the importance of components as distinguished from other aspects of adaptive functioning. In some cultures, the kinds of behaviors that matter to successful adaptation may be heavily influenced by the kinds of components that have been discussed in this chapter; in other cultures, behaviors that matter may be only minimally influenced by these components. In a hunting culture, for example, cleverness in tracking down an animal may be influenced by various kinds of information-processing components, but the bottom line is whether the hunter can kill the animal being tracked down. If hunters have poor aim with a stone, bow and arrow, or whatever, it doesn't matter how clever they have been in stalking the animal: there won't be any food on the table. The previous discussion in this chapter is most definitely biased toward the kinds of things that tend to matter in our own culture.

The 12 findings on intelligence just discussed provide only a very partial list of empirical generalizations in the literature on intelligence, but they cover sufficient ground to convey some sense of how the componential view accounts for various phenomena involving intelligence. As noted earlier, none of these generalizations is fully established; and the accounts provided here are certainly simplifications of the

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undoubtedly complex factors that lead to the phenomena covered by the generalizations. The componential view can account for a number of other findings as well, but it is worth emphasizing again that it does not account for or even deal with all phenomena involving intelligence, broadly defined. Although the various kinds of components form the core of the proposed intelligence system, they are by no means the only sources of individual differences (Sternberg, 1981b). First, components act on different informational contents, and the informational content can be expected to influence the efficacy with which components function in different individuals (Sternberg, 1977). Second, information can be presented in a variety of modalities (visually, orally, kinesthetically), and the modality of presentation can be expected to influence the efficacy of information processing (Horn, 1974, 1979). Finally, information processing will be affected by a host of motivational variables, each of which can have a substantial effect on performance (Zigler, 1971). Thus, the functioning of various kinds of components can be adequately understood only in the whole context in which they operate.

The componential framework sketched in this chapter is intended to furnish one possible start toward providing a unified outlook on a number of different aspects of intelligent functioning. In particular, it suggests (a) a classification scheme for various kinds of information-processing components, (b) ways in which these components might be interrelated, and (c) how the components and their interrelations can be used to account for various empirical phenomena that have been reported in the literature on human intelligence. The present framework is certainly not the only one that can provide suggestions of these kinds. But it seems like a useful supplement to existing frameworks that attempt to understand the cognitive bases of human intelligence and its manifestations.

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