Applying Cognitive Theory to the Testing and Teaching of Intelligence

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SUMMARY
This article describes how cognitive theory can be applied to the testing and teaching of intelligence. The article is divided into three main parts. The first part describes how the study of intelligence, traditionally an area that has been viewed as under the purview of differential psychology, has come squarely into the purview of cognitive psychology. The second part describes how the testing and teaching of intelligence, which in the past have been largely atheoretical, have been transformed into theoretically based enterprises guided by the theories of cognitive psychology. The last part describes a particular theory of intelligence, the triarchic theory, and how it has been applied to the problems of testing and teaching intelligence. It is concluded that cognitive psychology has given the study of intelligence a 'new lease on life', and that the testing and teaching of intelligence can and should be viewed as a primary focus of application for the principles of cognitive psychology.

When one thinks of applied cognitive psychology, one typically thinks of man–machine interfaces, human–computer interaction, and perhaps, selective applications of cognitive psychology to education. One rarely thinks of the testing or teaching of intelligence. Yet in the latter part of the 1980s the testing and teaching of intelligence have become a major potential focus of applied cognitive psychology. The goal of this article is to describe how this state of affairs has come about, and what form it takes. But in order to understand the application of cognitive psychology to the testing and teaching of intelligence it is first necessary to understand how the study of intelligence became intertwined with that of cognition in the first place.

HOW THE STUDY OF INTELLIGENCE BECAME A BRANCH OF COGNITIVE PSYCHOLOGY

Testing of intelligence

In most domains of psychology theory has preceded application. For example, engineering psychology developed largely as the application of cognitive and behavioural principles to man–machine interfaces. The field of intelligence is highly unusual in that, for the most part, application preceded theory, and in many instances theory and application never closely connected. This sequence of events seems more to reflect the history of the field of intelligence, rather than any necessary properties of this field.

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The study of intelligence originated in this century in large part as the result of a request from the French Ministry of Education in Paris to a psychologist, Alfred Binet. The request was that Binet devise a test that would provide a basis for making informed decisions as to whether children should be placed in classes for the mentally retarded. Previously, teachers had been recommending placement in classes for the retarded not only when children were genuinely retarded, but also when they were behaviour problems. Put simply, the teachers did not want these children in their classes, and had discovered a means to get them out. Thus, the problem was a very practical one: moreover, the purpose of intelligence testing was to protect rather than to penalize the children. Behaviour problems did not belong in classes for the retarded, and intelligence tests could provide a way of keeping them out.

Binet’s test, developed in collaboration with an associate, Theophile Simon, proved successful beyond all expectations. Binet and Simon’s test went through a series of revisions, and even the most recent version of this test is clearly the great-grandchild of the original version. Intelligence testers tend to be proud of the stability of their product (a disposition that has not been particularly favourable for the development of new products). In a speech at Yale University during the early 1970s, Henry Chauncey, then president of the Educational Testing Service, boasted that the Scholastic Aptitude Test (SAT) of today is very much like the one first devised by Carl Brigham roughly a half-century ago.

Intelligence testing might never have become big business were it not for the need during the World Wars to select and place recruits in jobs appropriate for their levels of ability. Psychologists such as Henry Goddard and Arthur Otis were called in to provide tests that would be appropriate for these purposes. They responded with enthusiasm, and formulated two instruments, the Army Alpha, which employed verbal material, and the Army Beta, which was non-verbal. By this time intelligence testing was firmly implanted in American society.

Clearly, tests were devised to serve practical purposes, and their construction reflected these purposes. Although some of the tests, such as the Thurstone Primary Mental Abilities Series, were based on psychometrically derived or tested theories of intelligence, most of the tests are essentially atheoretical in character. Moreover, the construction and selection of items reinforce the atheoretical nature of the enterprise. A good test item is considered to be one that has two basic properties. The first is a difficulty level that is neither too high nor too low. Extremely difficult and extremely easy items do not provide much discrimination among different levels of ability. The second property is a high item-total correlation. In other words, scores on a given item are highly correlated with scores on the test as a whole, with that item excluded. High item-total correlations increase the internal-consistency reliability of the test, and make the test more palatable to the test buyers and users. Somewhat paradoxically, perhaps, higher internal-consistency reliability often means lower empirical validity, because tests measuring only a narrow psychological construct are not likely to predict more complex external behaviour.

Although testing developed in a largely atheoretical manner, theorizing about intelligence was by no means either a dead or barren enterprise. A number of theorists proposed theories of intelligence based on the use of factor-analytic methods. These methods analysed observable individual differences in test
performance in terms of alleged latent psychological constructs. On the whole, the theories of intelligence derived from or tested by factor analysis tended to be structural rather than processual. They had more to say about what an alleged map of the mind might look like than about how mental processes might operate on this map. But the separation of psychometric theorists and theorizing from considerations of mental process has been greatly exaggerated in many people’s minds. Both Binet and Spearman, two of the differential theorists of intelligence, actually had cognitive accounts of intellectual performance (Binet and Simon, 1905; Spearman, 1923). Spearman, for example, proposed that much intellectual functioning can be understood in terms of three mental processes: the apprehension of experience (encoding of information), the eduction of relations (inference of rules), and the eduction of correlates (application of rules). Moreover, one of the more recent psychometric theorists of intelligence, Guilford, incorporated processes as one of the three facets of his structure-of-intellect model (Guilford, 1967, 1982).

But it was not the work of the psychometric theorists of intelligence that provided the invitation or impetus for cognitive psychologists seriously to undertake the study of intelligence. Rather, that task was taken on by Lee Cronbach, who in his 1957 presidential address to the American Psychological Association argued for the merging of two disciplines of scientific psychology (Cronbach, 1957). Some preliminary attempts at merger took place in the 1960s, most notably those represented in a book on Learning and Individual Differences edited by Robert Gagne (Gagne, 1967). But considerably more influential than these early attempts was the seminal paper published in the early 1970s by Earl Hunt, together with two colleagues (Hunt, Frost and Lunneborg, 1973).

Hunt, Frost and Lunneborg (1973), and later, Hunt, Lunneborg and Lewis (1975), provided a paradigm for the merger of the study of cognition and intelligence, a paradigm that later came to be called the cognitive-correlates approach (Pellegrino and Glaser, 1979). In this cognitive-correlates approach, subjects are presented with a battery of cognitive tests and a separate battery of psychometric tests. Performance on the cognitive tests is analysed in terms of its basic information-processing components, and scores on these components for individual subjects are correlated with scores on the psychometric tests. Hunt and his colleagues found low to moderate but statistically significant correlations, and their research led them to conclude that there are some, although not complete, overlaps between the cognitive skills measured on the laboratory tests and on the psychometric tests. Their claims went beyond mere postulation of a correlation, though. They argued, for example, that the ability rapidly to access lexical codes from long-term memory may be an important precursor of what we generally call ‘verbal ability’.

Some investigators, although acknowledging and appreciating the contributions made by Hunt, questioned whether the kinds of tests cognitive psychologists were using in the laboratory were the right ones to study if one’s goal was to understand the cognitive bases of intelligence. In particular, these psychologists believed that the laboratory tests were too simple to serve as bases for understanding intelligence, and that their use in the cognitive psychologist’s laboratory gave them no privileged status as a basis for understanding intelligence. These investigators, such as Sternberg (1977), Pellegrino and Glaser (1980), and Snow (1980), argued that higher-level tasks ought to be used, and in particular that a more appropriate
inroad for understanding intelligence could be had by taking intelligence-test items and decomposing performance on them into their elementary information-processing components. These investigators came to be known as cognitive components researchers (Pellegrino and Glaser, 1979).

The cognitive study of intelligence was now off to a racing start, and the results of this new interest took a number of forms; a new journal, Intelligence, was launched by Douglas Detterman, and continues to be published today. A number of books, both written and edited, appeared on the subject of intelligence (e.g. Resnick, 1976; Snow, Federico and Montague, 1980; Sternberg, 1977; Sternberg and Detterman, 1979). The cognitive study of intelligence was under way. At the same time that cognitive theory became a primary means for understanding intelligence, cognitive theory also became a useful means for measuring intelligence. The initial work was in the context of laboratory investigation, but eventually this work spread out toward the development of test batteries.

Hunt and his colleagues suggested that a number of cognitive paradigms could be used to assess various aspects of intelligence, but one paradigm caught on above all others. This was the letter-comparison paradigm initially suggested by Posner and Mitchell (1967). In this paradigm, subjects are presented with pairs of letters—such as AA, Aa, or Ab—that may be the same or different either physically or in name. For example, AA are the same both physically and in name; Aa are the same in name only, and Ab are the same neither in name nor in physical appearance. The subject’s task is to indicate as rapidly as possible whether the two letters are a match. In one condition people respond with respect to whether the letters are a physical match; and in another condition the same subjects respond with respect to whether the letters are a name match. The measure of interest is each person’s average name-match time minus physical-match time. This measure is considered to be an index of the time it takes a person to access verbal information in long-term memory. Physical-match time is subtracted from name-match time in order to obtain a relatively pure measure of access time that is uncontaminated by sheer speed of responding. The lexical-access task yields a remarkably consistent picture with respect to its relation to measured intelligence. Correlations with scores on verbal IQ tests are typically weak to moderate; about −.3. Hunt and his colleagues suggested that higher verbal subjects are better able to use information presented in a given amount of time, and hence to acquire new information in their long-term memory store.

The role of speed of lexical access seems to increase as the complexity of the decision motivating the access increases. Goldberg, Schwartz and Stewart (1977) had subjects perform a comparison task at three levels of complexity. The first level was simple physical comparison (e.g. are ‘A’ and ‘A’ a physical match?). The second level was homophone comparison (e.g. are ‘here’ and ‘hear’ a sound match?). The third level was taxonomic-category comparison (e.g. are ‘cat’ and ‘dog’ a match with respect to belonging in the category of animals?). These authors found a greater difference between the performance of preidentified high- and low-verbal subjects on the homophone and taxonomic comparison tasks than on the physical comparison tasks. The results suggest that the more ‘top-down’ the level of comparison, the greater the difference between high and low verbal.

It is instructive to compare the cognitive-correlates approach of Hunt and Goldberg et al. with the cognitive-components approach of Sternberg and Powell.
(1983). Sternberg and Powell, too, wished to measure cognitive precursors of verbal ability, but they were more top-down than even Goldberg et al. in their approach to the problem. They proposed that individual differences in verbal ability could be understood, in part, in terms of differential ability of individuals to acquire meanings of words from context (see also Jensen, 1980). Sternberg and Powell proposed a theory of how people learn from context. They then sought to test the theory by providing subjects with paragraphs to read, embedded within which were low-frequency words in the English language. A fragment of one such paragraph was as follows:

Two ill-dressed people—the one a tired woman of middle years and the other a tense young man—sat around a fire where the common meal was almost ready. The mother, Tanith, peered at her son through the oam of the bubbling stew. It had been a long time since his last ceilidh and Tobar had changed greatly; where once he had seemed all legs and clumsy joints, he now was well-formed and in control of his hard, young body.

Subjects were asked to define as best they could the meanings of oam and ceilidh. Through the use of their theory of decontextualization, Sternberg and Powell were able to predict relatively well the difficulties of various unknown words. But more importantly for present purposes, subjects' scores for the definitions tasks were correlated .62 with IQ, .56 with vocabulary, and .65 with reading comprehension scores. In other words, the correlational data suggest that the ability to learn from context is related to verbal ability, and it is reasonable to suppose that it is a precursor.

Not all of the work done in either the cognitive-correlates or cognitive-components approaches was directed toward the understanding of verbal ability. Other kinds of abilities were studied as well. (See Sternberg, 1984, 1985b for reviews of various cognitive approaches to the study of intelligence.)

Within the cognitive-correlates approach, Arthur Jensen suggested that choice reaction time can be a useful measure of what he believes to be a fundamental information-processing basis of intelligence, namely mental speed (Jensen, 1982). In a typical choice reaction-time experiment, the subject is presented with one of two or more possible stimuli, each requiring a different overt response. The subjects have to choose the correct response as rapidly as possible following the stimulus presentation. A correlation between choice reaction time and IQ tends to increase with the number of stimulus–response choices involved in the task. In other words, the larger the number of choices the subject has to make, and thus the more complex the choice reaction-time task, the more highly scores on this test correlate with measured intelligence.

Using the cognitive-components approach, Sternberg has studied the mental processes underlying tasks such as analogical reasoning (Sternberg, 1977) and syllogistic reasoning (Guyote and Sternberg, 1981; Sternberg, 1980). For example, in his 1977 book, Sternberg showed how analogical reasoning can be decomposed into roughly six elementary information processes: encoding a stimulus, inferring a relation between stimuli, mapping of the higher-order relation between the two halves of the analogy, application of the inferred relation to a new domain,
justification of a non-optimal response as nevertheless adequate, and response. Sternberg’s information-processing model accounted for large proportions of variance in the response-time data, and scores on individual components of information processing were shown to be correlated with scores on psychometric reasoning tests.

Whereas Hunt, Jensen, Sternberg, and others were originally content to measure intelligence within the context of laboratory experiments, Andrew Rose and his colleagues went beyond laboratory experiments, actually constructing an information-processing battery to measure individual differences in cognitive functioning (Rose, 1978). Rose’s battery consists of a large number of information-processing tasks, most of them from the laboratories of cognitive psychologists, consistent with the cognitive-correlates rather than the cognitive-components orientation. The tasks generally proved to be only weakly intercorrelated, and empirical validation data apparently were never collected, or at least never published. But Rose’s battery was an important step, because it represented the first serious attempt by a cognitive psychologist to construct a test battery that would rival the psychometric intelligence tests. In essence it conveyed the message that cognitive psychologists, too, could become involved in the testing business.

Teaching of intelligence

Whereas most of the early attempts at teaching intelligence were essentially atheoretical (see Spitz, 1986), some recent attempts have been more theoretically based.

Instrumental enrichment

One of these theoretical based programmes is Instrumental Enrichment (IE), Reuven Feuerstein’s well-known training programme (Feuerstein, 1980). The programme was originally designed for retarded children, but it has since been recognized by Feuerstein and others as valuable for upper-elementary and lower-secondary students at all levels of the intellectual spectrum. Based on Feuerstein’s theory of intelligence, the IE programme is intended to improve the cognitive functioning related to the input, elaboration and output of information. Feuerstein has compiled a long list of cognitive deficiencies he believes his programme can help to correct. Among them are (a) unplanned, impulsive, and unsystematic exploratory behaviour; (b) impaired or nonexistent capacity for considering two sources of information at once, so that the child deals with data piecemeal rather than grouping and organizing facts; and (c) inadequacy in experiencing the existence of an actual problem and subsequently in defining it. Feuerstein’s IE programme is designed to correct these deficiencies and, at the same time, to increase the student’s intrinsic motivation and feelings of personal confidence and self-worth.

A presupposition underlying Feuerstein’s programme is that children learn a great deal through what Feuerstein calls mediated learning experiences. The idea is that the child is not able to organize his or her environment fully, and so needs this environment interpreted through a mediator. The mediator is usually, at least initially, the mother, and to some extent the father. Parents, then, organize
experience for the child in order to help the child make sense of the world.

What are some of the characteristics of the Feuerstein programme? Instrumental Enrichment does not attempt to teach either specific items of information or formal-operational, abstract thinking by means of a well-defined, structured knowledge base. To the contrary, it is as content-free as possible. Its materials or ‘instruments’ each emphasize a particular cognitive function and its relationships to various cognitive proficiencies. Feuerstein defines an instrument as something by means of which something else is effected; hence the child’s performance on the material is seen as a means to an end, rather than as an end in itself. Emphasis in analysing IE performance is on processes rather than on products, so that the student’s errors are viewed as a means of insight into how the students solve problems.

The IE programme consists of 13 different types of exercises, which are repeated in cycles throughout the programme. Although the problems are abstract and ‘unworldly’, instructors are required to bridge the gap between them and the real world as much as possible. The following samples of the kinds of materials in the programme convey a sense of the types of activities in which the student engages:

1. Orientation of dots. The student is presented with a variety of two-dimensional arrays of dots and is asked to identify and outline, within each array, a set of geometric figures, such as squares, triangles, diamonds, and stars.

2. Comparisons. In one form of comparison exercise, the student is shown a picture at the left, say, of two small apples that have no internal shading or colouring. The student is also shown two pictures at the right, in one of which the student might see a single apple, larger than the ones at the left, and fully shaded inside. In the other picture, the student might see three upside-down apples that are also larger than the two apples at the left. The student’s task is to indicate, in each picture, which of the attributes of direction, number, colour, form, and size differ between the picture at the left and each of the pictures at the right.

3. Numerical progressions. In one kind of numerical progression problem the student is given the first number in a sequence and a rule by which the sequence can be continued, for example, +3, −1. The student then has to generate the continuation of the sequence.

Philosophy for Children

Philosophy for Children, Matthew Lipman’s programme (Lipman, Sharp and Osenanyan, 1980), is very different from the Feuerstein programme. Yet it seeks to foster many of the same intellectual skills.

Philosophy for Children consists of a series of texts in which fictional children spend a considerable portion of their time thinking about thinking, and about ways in which better thinking can be distinguished from worse thinking. The keys to learning are identification and simulation: Lipman hopes that through reading the texts, and participating in the classroom discussions and exercises that follow the readings, the students will identify with the characters and will simulate for themselves the kinds of thinking the children are shown to do. Like Feuerstein’s programme, Philosophy for Children is intended primarily for upper-elementary
and lower-secondary students, generally grades 5 through 8, although the programme has been extended both upward and downward.

Lipman has listed 30 thinking skills that his programme is intended to foster, a sampling of which includes the following:

1. **Concept development.** In applying a concept to a specific set of cases, children should be able to identify those cases that are clearly within the boundaries and those that are clearly outside the boundaries. With the concept of ‘friendship’, for example, children are asked questions such as whether people have to be of the same age to be friends, whether two people can be friends and still not much like each other, and whether it is possible for friends ever to lie to one another.

2. **Generalization.** Given a set of facts, students should be able to note uniformities or regularities, and be able to generalize these regularities from given instance to similar ones. For example, children might be asked to consider generalizations that can be drawn from a set of given facts, such as ‘I get sick when I eat raspberries; I get sick when I eat strawberries; I get sick when I eat blackberries’.

3. **Formulating cause–effect relationships.** Students should be able to discern and construct formulations indicating relationships between causes and effects. For example, students might be given the statement ‘He threw the stone and broke the window’, and then be asked whether the statement necessarily implies a cause–effect relationship.

As mentioned earlier, the skills trained through the Philosophy for Children programme are conveyed through a series of stories about children. Consider, for example, the first chapter of *Harry Stottlemeyer’s Discovery*, the central book in the series. As the students read about the consequences of Harry’s falling asleep in science class, they are introduced to a variety of thinking skills, such as the following:

1. **Problem formulation.** Harry says, ‘All planets revolve about the sun, but not everything that revolves about the sun is a planet.’ He realizes he had been assuming that just because all planets revolve about the sun, everything that revolves about the sun must be a planet.

2. **Non-reversibility of logical ‘all’ statements.** Harry says, ‘An all sentence can’t be reversed. If you put the last part of an all sentence first, it’ll no longer be true.’ For example, he cannot convert ‘All model airplanes are toys’, into ‘All toys are model airplanes’.

3. **Reversibility of logical ‘no’ statements.** Lisa, a friend of Harry’s, realizes that logical ‘no’ statements can be reversed. ‘No submarines are kangaroos’, for example, can be converted to ‘No kangaroos are submarines’.

4. **Application of principles to real-life situations.** Harry intervenes in a discussion between two adults, showing how a principle he had deduced earlier can be applied to falsify one of the adult’s arguments.

The most notable similarity between the Lipman and Feuerstein programmes is that both seek to train thinking skills. But given the basic similarity of goals, the
differences between the actual programmes are striking.

First, whereas Feuerstein’s programme minimizes the role of acquired knowledge and customary classroom content, Lipman’s programme maximizes such involvement. Although *Harry Stottlemeier’s Discovery* is basically philosophical in tone, the subsequent books in the programme—*Mark, Pixie, Suki, and Lisa*—each emphasize infusion of thinking skills into a different content area, such as the arts, social studies, ethics and science.

Second, whereas the material in Feuerstein’s programme is highly abstract and contains only a minimum of verbal material, the material in Lipman’s programme is conceptually abstract, but is presented through wholly verbal texts that deal with highly concrete situations.

Third, there is much less emphasis on class discussion and interchange in Feuerstein’s programme than in Lipman’s. Similarly, the written exercises are less important in Lipman’s programme.

Fourth, Feuerstein’s programme was originally designed for retarded learners, although it has since been extended to children at most points along the continuum of intellectual ability. Lipman’s programme seems more oriented toward children of at least average ability, on a national scale of norms. Moreover, the reading will be a problem for children much below their grade level in reading skills.

**A TRIARCHIC MODEL FOR TEACHING AND TESTING INTELLIGENCE**

The vehicle for teaching intellectual skills based upon the triarchic theory is a programme called *Intelligence applied: understanding and increasing your intellectual skills* (Sternberg, 1986). The programme is implemented as a course, and is appropriate for college students or for high-school students of at least average starting ability level. The course can be taught in a semester, but is better taught as a year-long programme. The main elements of the programme are the student text and a teacher’s guide, which contains a number of important elements that supplement the student text. These elements include: (a) a brief statement of the main goal of each chapter; (b) an outline of each chapter; (c) a list of the main ideas of each chapter; (d) a set of class discussion questions for each chapter; (e) a set of possible paper topics for each chapter; (f) supplementary activities for each chapter; (g) suggested supplementary readings; and (h) recommended time to be spent on each chapter, both for semester and for full-year courses. My goal in describing the programme will not be merely to summarize its main features, but rather to discuss the principles of intellectual-skills training it implements, and how it implements them. In other words, the focus of the discussion will be in terms of psycho-educational theory, rather than in terms of applying the programme to the classroom.

The vehicle for testing based on the triarchic theory is the Sternberg Multidimensional Abilities Test (Sternberg, in press), which is a test designed for students of kindergarten through college level. It includes verbal, quantitative and figural items that assess componential abilities, coping with novelty, automatization, and practical intelligence. The test will have nine levels, for kindergarten, grade 1, grade 2, grade 3, grades 4–5, grades 6–7, grades 8–9, grades 10–12 and college.
The triarchic model, which motivates this part of the article, has three basic parts. The first part of the theory, a componential subtheory, deals with the relationship between intelligence and the internal world of the individual. The second part of the theory, an experiential subtheory, deals with the relationship of intelligence to experience. The third part, a contextual subtheory, deals with the relationship of intelligence to the external world of the individual. Consider each of these three parts of the theory in turn. For more detail on the triarchic theory, see Sternberg (1985a).

Components of intelligence

The first part of the triarchic theory specifies the internal mental mechanisms that are responsible for intelligent behaviour. These mental mechanisms are referred to as information-processing components. A component is a mental process that may translate a sensory input into a mental representation, transform one mental representation into another, or translate a mental representation into a motor output. Components perform three basic kinds of functions. Metacomponents are higher-order processes used in planning, monitoring, and evaluating performance of a task. Performance components are processes used in the execution of a task. Knowledge-acquisition components are processes used in learning new things.

Teaching of componential processing

In Intelligence applied (Sternberg, 1986), instruction in componential processing comprises three separate chapters—one on metacomponents, one on performance components, and a third on knowledge-acquisition components.

Consider some of the problem types for one of the metacomponents—defining the nature of a problem.

The text opens with some real-world examples of how misdefinition of a problem can fundamentally impair one’s problem-solving ability. A first example involves a professor who misses his plane when, having failed to reach the airport limousine in time, he also fails to redefine the problem of how to make his plane on time. A second example is of people who, when they lack sufficient funds to meet their expenses, always define their problem as one of earning more money rather than of spending less money. A third example is of how misdefinition of the problem stemming from the break-in at the Watergate Hotel during a campaign for the presidency ultimately resulted in President Richard Nixon’s resignation. By defining their problem as one of covering up the break-in rather than as one of providing full disclosure in a minimally harmful way, the Nixon campaign committee seriously reduced the credibility of the Nixon administration. These and other examples help illustrate how proper definition of a problem is essential in everyday life.

The text moves on to strategies a student can use to help himself or herself define or redefine problems in a more nearly optimal way. These strategies include rereading or reconsidering the question that one seeks to address, redefining one’s goals in problem-solving, and asking whether the goal toward which one is striving
is really the goal that one wishes to reach. Each of these strategies is amplified in ways that make clear how the strategy can be applied to improving one’s problem-solving.

The text continues with exercises on defining the nature of a problem. Two such exercises are the nine-dot problem and the monk problem.

In the nine-dot problem the subject is presented with three rows, each containing three dots, for a total of nine dots. The problem the student faces is to connect all nine dots with a set of no more than four line segments, such that one’s pencil is never lifted off the page. The problem is quite difficult, and few students arrive at the correct answer spontaneously.

Most people assume that the line segments must be kept within the confines of the interior of the nine dots. They do not allow their solutions to extend beyond the boundaries of the dots. There is nothing in the problem that even suggests this constraint. Nevertheless, most people presuppose that it exists. This problem illustrates how people can make problem-solving difficult for themselves by introducing constraints into their solution processes that were never posed by the problem and, indeed, which make the problem impossible to solve.

In the monk problem a monk wishes to pursue study and contemplation in a retreat at the top of a mountain. The monk starts climbing the mountain at 7 a.m. and arrives at the top of the mountain at 5 p.m. of the same day. During the course of his ascent he travels at variable speeds, and takes a break for lunch. He spends the evening in study and contemplation. The next day the monk starts his descent at 7 a.m. again. Normally his descent would be faster than his ascent, but because he is tired and afraid of tripping and hurting himself, he descends the mountain slowly, not arriving at the bottom until 5 p.m. of the day after he started his descent. Must there be a point on the mountain that the monk passes at exactly the same time of day on the two successive days of his ascent and descent? If so, provide a plausible demonstration that this is the case. If not, show why this need not necessarily be the case.

In fact, it is necessarily the case that the monk must pass through exactly the same point on the mountain (altitude) at corresponding times on the days of his ascent and descent. The problem becomes much easier to conceptualize if rather than imagining the same monk climbing the mountain one day and going down the mountain the next, one imagines two different monks, one ascending the mountain and the other descending the mountain on the same day. You may assume that the monks start and finish at the same time, although this assumption is not necessary for solution of the problem. Note that in this redefinition of the problem, the monk’s descent on the second day is reconceptualized as a different monk’s descent on the same day as the first monk’s ascent. This reconceptualization does not change the nature of or solution to the problem, but only makes it easier to see what that solution is. This kind of problem shows how, when it is difficult to solve a problem in the form in which it is posed, it is sometimes much easier to solve the problem if the problem is reconceptualized in an isomorphic (equivalent) way such that the surface structure, but not the deep structure, of the problem changes.

Consider next the teaching of performance components. Consider as an example of the teaching of performance-componental functioning the teaching of just one performance component, inference.
The text on inference opens with a description of what inference is, and a real-world example of how it is used. When one hears that a friend is in the hospital, one is likely to infer that the friend is either ill or injured. Nothing in what one may have heard directly states this. It is possible, for example, that the friend is merely visiting someone in the hospital or has taken a job in the hospital. But unless one has evidence to the contrary, one is quite likely to infer that there is a problem, and to become concerned.

The text continues to describe different kinds of verbal inferences, such as similarities, contrasts, predication, subordination, coordination, superordination, and so on. Each of these kinds of inference is described, and then students are given an opportunity to recognize each of them. For example, given the pair of words, **human** : **mammal**, the student is asked to say what the relation is and to classify the inference. In this case, a human is a mammal and the correct classification is subordination.

After this training on fairly formal kinds of inferences the students are given training on various kinds of inferential fallacies that are made in the practical reasoning of everyday life. Nineteen different fallacies are described, exemplified, and used as bases for exercises. Included among the fallacies are errors of reasoning such as irrelevant conclusions, hasty generalizations, appeal to authority, and composition. Consider the form the actual text takes for the fallacy of composition:

A fallacy of composition is committed when one reasons that what is true of parts of a whole is necessarily true of the whole itself.

Consider an example of the commission of the fallacy of composition:

When forming his panel of advisors, the newly elected governor chose the best person for each advisory position. The governor bragged to the press, 'I'll have the most effective, efficient advisor panel any governor could have, because I have the best people on my panel.'

In this instance the governor is assuming that even if it is the case that each of the people who is on his committee is maximally effective and efficient, this effectiveness and efficiency will carry over to the panel as a whole. However, there is no guarantee that even if each individual works well by himself or herself, the individuals will work well collectively. They may, in fact, spend all their time arguing.

Here is another example of the fallacy of composition in action. Can you spot the fallacy?

Jill went to Warren's apartment for a cocktail before they were to go out to dinner. Warren asked Jill if she would like beer or wine. Jill said, 'Well, I like beer and wine equally well and really can't decide between them now, so why don't you put both beer and wine into my glass?'

Can you think of any examples where you or others have committed the fallacy of composition, thereby distorting your inference processes?

The descriptions of each of the 19 kinds of fallacies are followed by 25 vignettes, some of which have embedded within them fallacies in informal reasoning and
others of which do not. The student must indicate which vignettes exemplify fallacies, and for those that do, say what the fallacies are.

The student has the opportunity to employ the performance component of inference, as well as other performance components, in both verbal and geometric analogies, series completions, classifications, and matrix problems. These problems give the student the opportunity to employ these processes of reasoning in rather formal and abstract kinds of problem-solving tasks. However, students also have the opportunity to apply the performance components in more concrete situations.

The chapter ends with two kinds of practical reasoning problems that require inference as well as the other performance components: legal reasoning problems and clinical reasoning problems. In the legal reasoning problems, students are presented with a brief story describing a legal proceeding, followed by some facts extracted from the case, some imaginary principles of law, and a choice of two outcomes for the legal proceeding. First, the student needs to infer which principle of law from among those given is most relevant to this particular case. The student indicates which of the principles he or she has chosen. Then the student needs to encode which facts this principle most directly bears upon. The student must select the critical fact. Finally, the student needs to apply the principle that has been chosen to the fact that has been chosen in order to decide the outcome of the case. The student indicates his or her response. Consider an example of a legal reasoning problem.

Mr Taylor was hired under a contract to command an ocean-going ship belonging to Mr Mayer. The ship was to sail from San Francisco to Manila and back. While in Manila, Taylor had a fight with the first mate, and he resigned his command. A new captain was appointed. However, because the radio had been knocked out in a storm, notice of this change was not communicated to Mr Mayer. Taylor helped the new captain on the trip back to San Francisco. The ship arrived safely. No damages had resulted from the change of command.

When the ship arrived in San Francisco, Mayer learned the above facts. He paid Taylor for his services as captain up to the time he quit, but he refused to pay him for his services in helping get the vessel home. Taylor sued Mayer to recover wages for his services on the return trip. Will Taylor win?

**Principles**

1. A man is not required to pay for that which he has had no opportunity of rejecting. Under circumstances where there is no opportunity of rejecting, acquiescence cannot be presumed to arise from silence.

2. If one of two parties to the contract breaks the obligation which the contract imposes and the other party is injured due to the break, then the injured party has the right of action for damages.

**Facts**

1. Taylor voluntarily resigned his command.
(2) Mayer did not learn of Taylor’s resignation until the ship arrived home.
(3) Taylor helped the new captain on the return trip.
(4) The ship arrived safely in San Francisco.

Outcomes
(1) Taylor will win.
(2) Taylor will lose.

The answer to this problem is: Principle 1, Fact 2, and Outcome 2.

Finally, consider teaching of knowledge-acquisition components. In *Intelligence applied*, emphasis in teaching of knowledge-acquisition components is on learning of vocabulary from context.

According to the theory, three general kinds of skills are involved: knowledge-acquisition components, use of these components on context cues, and effective handling of mediating variables that render application of the components to the cues more or less difficult.

The training starts with an exposition regarding three processes of knowledge-acquisition: (a) selective encoding, by which information relevant to deciphering the meaning of the word is separated from information irrelevant to that purpose; (b) selective combination, by which relevant information is combined; and (c) selective comparison, by which old information is brought to bear upon the learning of the new word.

Context cues are kinds of information to which the knowledge-acquisition components can be applied. There are eight types of context cues: (a) setting cues, (b) value/affect cues, (c) stative property cues, (d) active property cues, (e) causal/functional cues, (f) class membership cues, (g) antonymic cues, and (h) equivalence cues. Students receive exercises on the application of the three processes to each of these kinds of cues.

Mediators are the variables that make application of the knowledge-acquisition processes to the contextual cues either easier or more difficult. Seven mediators that have been identified as particularly important in learning words from context are (a) the number of occurrences of the unknown word, (b) the variability of the contexts in which multiple occurrences of the unknown word appear, (c) the importance of the unknown word to understanding the context in which it is embedded, (d) the helpfulness of the surrounding context to understanding the meaning of the word, (e) the density of unknown words in the passage, (f) the concreteness of the unknown word and of the surrounding context, and (g) the usefulness of the previously known information in understanding the passage or understanding the meaning of the unknown word.

Each of the concepts in this theory is explained and illustrated through the use of passages that require learning of words from context. Consider an example of one of the seventeen passages used to illustrate these concepts:

Although the others were having a marvelous time at the party, the couple on the blind date was not enjoying the merry-making in the least. A *pococurante*, he was dismayed by her earnestness. Meanwhile, she, who delighted in men with full heads of hair, eyed his substantial
phalacrosis with disdain. When he failed to suppress an eructation, her
disdain turned to disgust. He, in turn, was equally appalled by her
noticeable podobromhidrosis. Although they both loved to dance, the
disco beat of the music did not lessen either their ennui or their mutual
discomfort. Both silently vowed that they would never again accept a
blind date.

Students have to define the unknown words by using the context cues. The
meanings of the unknown words are:

- pococurante—a nonchalant or indifferent person;
- phalacrosis—baldness; a bald spot;
- eructation—a belch;
- podobromhidrosis—smelly feet.

Through the use of the aspects of the theory it becomes possible to improve one's
ability to learn meanings of words from context, and thereby to improve one's
vocabulary.

Testing of components

On the Sternberg Multidimensional Abilities Test, functioning of the three kinds of
components is tested in an integrated rather than separated fashion. Thus the
relevant subtests collectively measure metacomponential, performance-component-
tial, and knowledge-acquisition componential functioning in verbal, quantitative,
and figural modes. Consider some examples of subtests.

Figure completion is a test used in the kindergarten through grade 5 levels.
Figure completion items assess a student's ability to complete a sequence of shapes
that is progressing according to certain rules. In order to solve the problem,
students must figure out the rule creating the sequence and then apply that rule to
choose the correct answer. For grade six through college, figural matrices instead of
figural completions are used. Figural matrices assess the ability to discern the
relationships among shapes of a matrix and to supply a missing figure in that
matrix.

Another kind of item type, used for kindergarten through college, is learning
from context. These items assess a student's ability to use cues in a short sentence
or passage to figure out the meaning of an unknown word that is part of the
sentence. The unknown word is represented by a pronounceable consonant-vowel-
consonant syllable. The idea is to measure a student's ability to learn, rather than
what is already learned, as would be assessed by vocabulary. Finally, quantitative
reasoning ability is assessed through number series problems, which require
students in grades 4 through college to complete series of numbers. Younger
students receive instead a test of basic quantitative understanding.

Experience and intelligence

According to the triarchic theory there are two facets of a person's experience with
tasks or situations that are particularly critical to intelligent behaviour. These facets
are the ability to deal with novel kinds of tasks and situational demands, and the
ability to automatize information processing.
Teaching of coping with novelty and automatization
One of the most important mental skills for dealing with novelty is that of insight.

Janet Davidson and I (Davidson and Sternberg, 1984; Sternberg and Davidson, 1982) have proposed that insights can be of three kinds: (a) selective encoding insight, (b) selective combination insight, and (c) selective comparison insight. The selective processes became insightful when, in applying the corresponding knowledge-acquisition component, the individual finds that there are no obvious context cues to which to apply them. Consider the training elements for just one of the three insight processes—selective encoding.

It is pointed out to the student that significant problems generally present one with large amounts of information, only some of which is relevant to problem solution. For example, the facts of a legal case are usually both numerous and confusing. An insightful lawyer must figure out which of the myriad facts confronting him or her are relevant to principles of law. Similarly, a doctor or psychotherapist must sift out those facts that are relevant to diagnosis or treatment. Perhaps the occupation that most directly must apply insights of this and other kinds is that of the detective: in trying to figure out who has perpetrated a crime the detective must figure out what the relevant facts are. Failure to do so may result in the detective’s following up on false leads, or in his or her having no leads to follow up on at all.

The description of selective encoding is followed by an example problem in which selective encoding is important: the evidence on the basis of which scientists have offered explanations for the total extinction of the dinosaurs and other creatures 65 million years ago. Facts surrounding the extinction are presented, and the student is asked to contemplate which of these facts are relevant to figuring out the cause of the extinction. A series of steps is described by which relevancy judgements can be made.

This use of selective encoding is followed by arithmetical and logical word problems requiring selective encoding. First, the student is shown how to apply selective encoding to the problems. Then the student is given the actual problems. Some examples of such problems are:

1. One day, a lady hailed a passing taxicab. On the way to her destination, the lady chattered incessantly. The taxi driver got annoyed. In desperation, he finally said, ‘Lady, I can see in the mirror that you are trying to talk to me. I’m very sorry, but I cannot hear a single word you are saying. I am extremely hard of hearing, and my hearing aid has not worked all day.’ When the lady heard this, she stopped talking, feeling very sorry for the driver. But after she got out at her destination, paid her fare, and watched the cab drive away, she suddenly realized that the driver had lied to her. How did she know that the driver had lied?

2. Susan gets in her car in Boston and drives toward New York City, averaging 50 miles per hour. Twenty minutes later, Ellen gets in her car in New York City and starts driving toward Boston, averaging 60 miles per hour. Both women take the same route, which extends a total of 220 miles between the two cities. Which car is nearer to Boston when they meet?

3. On a certain house two halves of a roof are unequal: the right half slopes downward at an angle of 35 degrees, whereas the left half slopes downward at
an angle of 75 degrees. Suppose a rooster lays an egg right on the peak of the roof. On which side of the roof can the egg be expected to fall?

In Problem 1 the lady knew that the taxicab driver was lying because he had taken her to the destination that she had already asked him to take her to. The critical information is that she had, indeed, arrived at her requested destination. In Problem 2, each car is at the same distance from Boston when they meet, as the cars are immediately next to each other. The critical fact is that the cars have indeed met. In Problem 3, the answer is simply that roosters do not lay eggs. The critical information here is that the problem claims that the rooster has laid an egg.

The arithmetical and logical word problems are followed by information-evaluation problems. In each of these problems students are presented with a question and a number of facts taken from the story. They are to mark each fact as either relevant (R) or irrelevant (I) for answering the questions. In some cases pieces of information may be relevant only when considered in conjunction with each other. In such cases both pieces of information are to be marked as relevant. Consider an example of an information-evaluation problem:

Why do television sets with cable connections get better reception than do televisions with antennae?
(a) Televisions flash pictures on a screen at a rate of thirty pictures per second and so produce the effect of continuous motion.
(b) At the broadcast station, a television image must be analyzed into 200,000 electrical charges.
(c) Each of the 200,000 charges is discharged 30 times per second and transmitted to the viewers.
(d) The picture can be transmitted by a coaxial cable, which travels directly from the broadcast source to the viewer.
(e) Most television pictures are transmitted by waves (high-frequency short waves) similar to those used by radio stations.
(f) High-frequency short waves can only travel in straight lines; they cannot bend to follow the earth's surface. Their range is limited to the visual horizon.

The answers to the problem are (a) irrelevant, (b) irrelevant, (c) irrelevant, (d) relevant, (e) relevant, and (f) relevant.

The information-evaluation problems are followed by mystery problems. It was noted earlier that the prototypical situation for the application of insights is the situation faced by the detective trying to solve a crime. Selective encoding can be particularly important in detective work. Consider an example of a mystery story, and how selective encoding is critical to solving it.

Trying to fight his seasickness, Detective Ramirez went through the long corridor that led to the cabin of the late Mr Saunders. Once he got to the cabin Detective Ramirez saw Mr Saunders's body slumped over the dresser. A small gun lay in one of his hands. Approaching the dresser, Ramirez could see some loose papers on it. Among them was a suicide note. In the suicide note, Mr Saunders explained why he had suddenly decided to end his life. A pen without its cover was also on the dresser.
While reading the suicide note, Ramirez thought he would never understand how a famous writer such as Saunders could have committed suicide. Saunders was Detective Ramirez's favorite mystery writer, so Saunders's death upset him very much.

Ramirez shifted his eyes from the note to Saunders's body, which was lying on its left side. Saunders had been a tall man in his forties with fair complexion and blond hair that somehow masked a long scar on his right cheek. The body was dressed in a well-cut dark suit that showed the writer's taste for the good things in life. 'What a loss,' Ramirez thought.

A noise in the background reminded Ramirez that there were two more people in the cabin besides him: the ship's captain and Mr Saunders's nephew, Mr Prince, who was the one who had discovered the body. Detective Ramirez asked Prince to tell him everything he had heard or seen regarding the incident.

'We came back to Mr Saunders's cabin shortly after the captain's reception was over,' said Mr Prince. 'Mr Saunders—my uncle—told me he wanted to be alone. He wanted to take some notes for his next book. So I left the cabin and went directly to my own cabin, which is next door.'

'What happened after that?' asked Detective Ramirez.

'Shortly after I left, I heard a shot,' Mr Prince continued, 'and when I came in I saw my uncle's body slumped on the dresser. I called his name but I did not get any reply, so I went closer to see why he did not answer and then I noticed the bullet through his left temple.'

'Did you touch anything?' asked Detective Ramirez.

'No, I did not. I left everything the way it was.'

Ramirez was certain that the apparent suicide was in fact a murder. He said to Mr Prince, 'You'd better tell me the whole truth.' How did Detective Ramirez know that Mr Saunders's death was murder, not suicide?

The answer to this mystery is: Mr Prince could not have known his uncle had a bullet through his left temple unless he had moved the body. Mr Saunders fell on his left side and Ramirez noticed Saunders's right cheek, which has a scar on it.

When one reads a newspaper or magazine article, unless the article is technical or poorly written, one is scarcely aware of the mental processing being done while reading is taking place, despite the enormous complexity of the reading process. Skilled readers can concentrate on absorbing new facts and ideas in the article without having to pay attention to things such as what the individual letters of each word are, how the words are pronounced, how the words fit together to form sentences, what the words mean, and so on. However, for students starting elementary school it is not possible to devote so much attention to absorbing the main facts and ideas of a newspaper or magazine article. Rather, such students have to concentrate on some of the basic processes—such as letter and word encoding. Stated in another way, the adult reader has automatized the lower-level information processing involved in reading, and hence is able to devote most of his or her mental resources to deciphering the higher-level information contained in
the text. The young child has not automatized fully the processes of reading and hence must devote relatively more of his or her attention to lower-level processing.

The instruction on automatization starts out with practical examples of automatization such as the reading example given here, but also through examples of driving and touch-typing. The examples show the distinction between controlled and automatic processing. According to Schneider (1982), controlled processing (a) is comparatively slow, (b) is sequential in nature, (c) is effortful, (d) is under conscious control, (e) is limited by short-term memory, and (f) requires little or no training to develop. Automatic processing (a) is relatively fast, (b) is executed in parallel, (c) is almost effortless, (d) requires extensive practice to develop, (e) is not limited by short-term memory capacity, and (f) is for the most part beneath conscious control (i.e. it is subconscious). Tasks such as reading, playing the piano, and driving require largely controlled processing when they are first learned, but later require primarily automatic processing.

The discussions and examples of controlled and automatic processing are followed by 10 principles for facilitating automatization, based upon Schneider’s (1982) research. Examples of such principles are that consistency in information processing is a necessary condition, and that automatization is primarily a function of correct execution of the process or processes to be automatized. Thus, whereas in many kinds of learning one learns from one’s mistakes, in automatization one learns from one’s successes.

The principles are followed by four kinds of exercises for developing automatization skills: (a) letter comparison, (b) visual search, (c) digit–symbol, and (d) letter scanning. Consider examples of two of these tasks: letter comparison and digit–symbol.

In the letter-comparison task, subjects are presented with several sets of letter pairs. Each set contains 80 pairs of letters. The subjects’ task is to scan these pairs of letters rapidly and in order, and to indicate whether each pair of letters has the same name or a different name. For example, the following pairs are composed of letters with the same name: AA, Dd, FF, nn. The following pairs are composed of letters with different names: BK, Nb, gF, he. For each pair the student has to indicate as quickly as possible whether the letters are the same (S) or different (D). The students time themselves as they work through the letter pairs, and attempt to improve their speed without making mistakes.

In the digit–symbol task the student is presented with a set of digits paired with a set of symbols. Following the key that indicates how the digits and symbols are paired, one finds a large number of the symbols in isolation. One’s task is to indicate the appropriate digit for each symbol. For example, one might be given the pairings $1 \times , 2 , (3 + , 4) ?$. One’s task would be to indicate for each symbol the appropriate digit. This task has been widely used on tests of intelligence. Students receive nine sets of pairings. Each set of items contains from five to eight pairings followed by 120 symbols. Students are encouraged to work as rapidly as possible and to try to increase their speed while maintaining perfect or near-perfect accuracy.

Testing of the ability to cope with novelty and of automatization
On the Sternberg Multidimensional Abilities Test, coping with novelty is assessed.
through the way in which a person reasons with counterfactual material. Consider some examples of relevant subtests.

Counterfactual data items, for grades kindergarten through 3, assess the ability to reason with altered quantitative concepts. The teacher reads aloud a counterfactual statement (‘pretend . . .’) that establishes a quantitative concept that is the opposite of what students know to be true. The student must assume that the statement is true and then reason with the counterfactual concept in order to select the appropriate picture. In novel verbal analogy items, for grades 4 through college, examinees must reason with altered states of the world in order to infer relationships between pairs of words. A counterfactual statement precedes each analogy. The student must assume the statement is true and then complete the analogy based on the novel information. An example of such an item would be ‘suppose that all carrots are turtles’. Which completion would now be correct?

Person is to house as carrot is to (a) shell, (b) food, (c) room, (d) rabbit. The correct answer is (a). In novel figural problems examinees must imagine that a given shape is a different shape, and then reason as though this transformation were the case.

Automatization is tested through the use of the Posner and Mitchell (1967) test, as described earlier. Subjects are given a large number of matchings involving letters, numbers, or figures. They must make either physical or conceptual matches. The matching tasks are highly speeded, and when examinees are able to automatize performance on these items they generally receive higher scores.

**Intelligence in context**

*Teaching of practical intelligence*

The goal of the unit on practical intelligence is to reinforce application of mental processes to real-life tasks and situations. Students are given some examples of why practical intelligence is important in their everyday lives, and then are presented with some alternative views on the nature of practical intelligence. Finally they are given a variety of kinds of exercises to help them develop their practical intelligence. Consider some of the kinds of exercises presented.

First, students are presented with an adaptive behaviour checklist, based upon research by Sternberg, Conway, Ketron and Bernstein (1981). The checklist can be used as an instrument of self-evaluation. One can rate the extent to which each of the set of behaviours characterizes oneself. These behaviours fall into three broad categories: (a) practical problem-solving ability, (b) verbal ability, and (c) social competence. Examples of behaviours for each of these three factors are, for practical problem-solving ability: (a) reasons logically and well, (b) identifies connections among ideas, and (c) sees all aspects of a problem. Examples of behaviours for verbal ability are: (a) speaks clearly and articulately, (b) is verbally fluent, and (c) converses well. Examples of behaviours for the social-competence factor are: (a) accepts others for what they are, (b) admits mistakes, and (c) displays interest in the world at large.

An important aspect of everyday life is the ability to decode non-verbal messages that people send. Such non-verbal messages, emitted during the course of a conversation may, in some cases, correspond to what a person was saying, but in other cases it may not. Often the non-verbal messages are a better indication of a
person's true feelings than are the verbal messages that they accompany. And it is therefore quite important to be able to decode such messages. Indeed, they may tell one more than do the person's words.

In a non-verbal-decoding task, students are presented with pictures of pairs of individuals. The first 20 pairs are of heterosexual couples. Ten of the couples are genuinely involved in romantic relationships; the other ten are not. The students' task is to guess which couples are involved in relationships, and which are not. In the second set of pictures, students see sets of two individuals, one of whom is the other's supervisor. Their task is to guess who is the supervisor of the other individual.

In addition to receiving practice in decoding non-verbal signals, students are given instruction in the kinds of things to look for. The idea is to sensitize them to the kinds of cues people emit in various situations. For example, in the case of the couples, our research has indicated that relevant cues are: (a) level of relaxation, (b) body lean, (c) positioning of arms and legs, (d) tenseness of the hands, (e) match in socioeconomic class, (f) distance between bodies, (g) amount of physical contact, and (h) general similarity. A similar set of cues exists for the supervisor-supervisee task. Thus, students learn that there can be as much information to be gleaned from non-verbal communications and interactions as from verbal communications.

Students are next exposed to 20 everyday situations that present three options representing alternative ways of handling these situations. One of the options represents a solution of adaptation—trying to accommodate oneself to the environment. A second option represents a solution of selection—deciding to leave that environment altogether. The third option represents a solution of shaping—attempting to accommodate the environment to oneself. Students consider the available information, and decide which of these kinds of solutions is best.

In problems such as these there is no one right or wrong answer. To the contrary, the 'right' answer would depend on the individual, the situation, and the interaction between the two. The students' goal, therefore, ought to be to find the course of action that is right for that individual.

Following the everyday situations is a set of tacit-knowledge tasks. Tacit knowledge is knowledge picked up by osmosis from one's experience. It is usually not explicitly taught. Although the tacit knowledge needed for success varies from one occupation or life course to another, practically intelligent individuals tend to be those who are good at putting themselves in others' shoes. In other words they tend to know how to use the knowledge they have to make right decisions, and to be able to apply this knowledge to a broad range of types of tasks. The tacit-knowledge tests require the student to play two roles—that of a business executive and that of a professor in a university psychology department. The student's goal is to answer each question as though he or she is either a business executive (for the first set of questions) or a professor (for the second set of questions). The questions assess the students' abilities to manage themselves, manage others, and manage tasks. Although the abilities are exercised, in the book, only within two specific content domains, they are obviously quite general ones.

The last kind of exercise in the unit on practical intelligence is on conflict resolution. Students are presented with examples of everyday kinds of conflicts, and have to indicate the desirability of each of several styles of conflict resolution.
Testing of practical intellectual skills
A first type of item used in the Sternberg Multidimensional Abilities Test to measure practical intellectual skills is route planning. This subtest is used for kindergarten through college. Items on this subtest assess the ability to reason with visual information. A map precedes the items, and the student is asked to make decisions about particular routes. The items stress practical reasoning and planning rather than map reading. Items are not based on knowledge of directions or prior knowledge of maps.

A second kind of item is the practical data item. Items of this kind, used for all levels, assess the ability to deal with ‘real-world’ quantitative information. The examinee is given a set of ‘practical’ information and is then asked to reach conclusions based on this information. These items are intended to measure practical reasoning rather than reading or mathematics achievement, and so vocabulary and mathematics knowledge are kept at a low level.

To conclude, the triarchic theory of intelligence provides an expanded conception of the range of intellectual abilities that constitute intelligence, and specifies in some detail what these abilities are. The theory has undergone extensive validation (Sternberg, 1985a), and appears to account for a variety of kinds of intellectual performances in individuals of varying ages. In this part of the paper I have shown how this theory can be applied in two distinct but interrelated ways: through teaching and through testing of intelligence. The triarchic theory is a culmination of a great deal of past theory and research on intelligence although, as with all other theories, it is a temporary culmination. It provides a means to apply cognitive psychology in a way that is potentially somewhat more constructive than has been the case in much of the past work on intelligence.

Because both the Sternberg Multidimensional Abilities Test and the Intelligence applied programme are so new, summative evaluation data are not yet available. Indeed, the test is not even published yet! However, more than a decade of developmental research underlies both instruments.

Several of the constituents of the Intelligence applied programme have been validated in their own right.

In one set of studies (Sternberg, 1987), adult subjects were placed in one of five groups of a study of methods for teaching learning-from-context skills. In one group the subjects received a pre-test and a post-test, each measuring decontextualization skills. But in this control group they received no experimental treatment at all. In a second control group there was a treatment, but the treatment was merely practice in decontextualization. Subjects did not receive any theory-based training. In each of three treatment groups subjects did receive theory-based training. In one experimental group the subjects received training in processes of decontextualization; in a second such group they received training in the context cues to which the processes could be applied; in the third experimental group subjects received training in the mediating variables that determined how well the processes could be applied to the cues. The treatments in the three training groups correspond to the three elements of Sternberg and Powell’s theory of learning from context. Subjects in all three experimental groups improved significantly and substantially more from pre-test to post-test than did subjects in either of the control groups. Moreover, subjects in the practice control condition did not improve any more than did subjects in the no-practice control condition. In other words, it was theory-based
instruction rather than more practice that was responsible for the gains in the experimental groups.

In another study (Davidson and Sternberg, 1984), we found effects of training of insight skills for students in the upper elementary grades (4–6). Experimental subjects received insight training similar to that in *Intelligence applied*, except for the modification of the material to be suitable for young children. The processes taught—selective encoding, selective combination, and selective comparison—were identical to those taught in the process condition of the learning-from-context training study. The difference was that here the processes were applied to more insightful kinds of problem-solving. A pre-test–post-test design was used for both experimental (trained) and control (untrained) subjects. Trained subjects improved significantly and substantially more than did untrained subjects. Moreover, these differences extended to transfer problems, which overlapped with the problems in the training in terms of the processes, but not the content involved in the problems. A year later, experimental subjects were given a post-post-test, and compared to a new control group. (The old control group had since been trained.) Scores on the post-post-test showed no decline from the post-test, and were significantly higher than the scores of the controls.

Most of the subtests of the Sternberg Multidimensional Abilities Test have been validated in carefully controlled experimental studies, as reported in Sternberg (1985a). These validations have generally consisted of two parts: internal validation, in which a cognitive model of task performance is fit to response-time or error data (or both), and external validation, in which model parameters for individual subjects are correlated with external criteria.

For example, series completions, used as a measure of componential abilities, have been studied fairly extensively by Sternberg and Gardner (1983), as well as by other investigators. Sternberg and Gardner found that a small set of basic performance components accounts for performance on three inductive-reasoning tasks (analogies, series completions, and classifications) for three different task contents (schematic picture, verbal, geometric).

Another test—this one of the ability to cope with novelty—is counterfactual analogies, in which an examinee is presented with a counterfactual statement, and then must assume that this counterfactual is true in the solution of the analogy. This form of item was used by Marr and Sternberg (1986) to compare problem-solving strategies of gifted versus non-gifted youngsters. They found that the gifted youngsters did not devote more attentional resources to studying counterfactual information unless that counterfactual information was relevant to problem solution, which was the case for only half the items.

Another of the subtests used in the multidimensional test, this one to measure contextual (practical) intelligence, requires examinees to recognize common inferential fallacies. In an unpublished study, Susan Nolen-Hoeksema and I found that the ability to recognize such fallacies shows only a small although significant correlation (about .2) with the kinds of reasoning problems found on intelligence tests. In other words, formal and informal reasoning appear to be largely independent skills.

To summarize, although there have not yet been summative evaluations of either the test or the training programme based on the triarchic theory of intelligence, the formative-evaluation data are promising and show the potential of theory-based instruments.
CONCLUSION

Cognitive theory is now being successfully applied in two practical domains of education: testing and training. Whereas these domains were at one time all but divorced from such theory, today they are being closely integrated with it. Current research shows the importance of integrating theory with testing and training. Through cognitive testing, we can obtain a much more refined picture of cognitive abilities than was ever before possible; through cognitive training, it is possible to get some fairly striking gains in cognitive skills in relatively short periods of time (Davidson and Sternberg, 1984; Sternberg, 1987). In education, the time is truly at hand for the application of cognitive theory to testing and training.

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