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ABSTRACT

The use of standardized tests and test data to detect and address differences in cognitive styles is advocated here. To this end, the paper describes the componential theory of intelligence addressed by Sternberg et. al. This theory defines the components of intelligence by function and level of generality, including: (1) metacomponents: higher order processes involved in decision-making, planning, and evaluation; (2) performance components: processes used to manipulate and transform information in the performance of a task; (3) knowledge-acquisition components: processes involved in learning new and contextual information; and (4) general, class, or specific level of generality. The paper also reviews the literature on identification of specific components associated with specific cognitive processes and the trainability of those processes. Following the definition and description of these information processing constructs, their use in both constructing test items and analyzing student outcomes from standardized tests is advocated. Such qualitative test analysis could possibly then be used, not just to describe or predict performance, but also to detect differences in cognitive styles and diagnose and remediate areas of weakness. (JGL)

Toward a Qualitative Analysis of Standardized Tests Using an Information Processing Model

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> The educational products requirements of the nation are more frequently being defined in terms of our capability to provide postsecondary educational opportunities for the majority of our youth, and a continued program of learning for most of our citizens. If this trend continues, selection and prediction can no longer be allowed to dominate in the technology of psychoeducational appraisal; rather, the stage must be shared, with an emphasis on <u>description</u> and <u>prescription</u> (i.e., the qualitative description of intellective function leading <u>not</u> to the selection of those most likely to succeed, but to the prescription of the learning experiences required to more adequately ensure that academic success is possible (Edmund W. Gordon, 1976, p.33)

This quotation, written almost a decade ago is even more relevant today at a time when there is a growing public concern that the quality of education in our nation's schools seems not to reflect the kinds of knowledge and competencies that students will need for life in the 21st century. Part of our dissatisfaction with traditional standardized tests then as it is now, stems from the impression that they serve very limited pedagogical purposes. Test data provide us with general information with respect to positive, neutral or negative impact of educational treatments, but offer minimal information on specific aspects of achievement or failure to achieve and thus do not encourage efforts at relating specific aspects of achievement to specific aspects of treatment. Test data are often used to inform the decision making process with respect to the selection of students for entrance into educational programs and to predict their performance when exposed to these opportunities. However, they are limited in their utility for the conduct of instruction or guidance of learning. At best, test data analysis provide gross characterization of success and failure of students in relation to some reference group (e.g., percentile rank or grade equivalent) but they tell us little about the adequacy of performance, are insensitive to differential response tendencies and do not reflect the process by which achievement is developed (Gordon, 1976).

The position being advanced here is that the generation and interpretation of test data should serve diagnostic functions more adequately so that pedagogical intervention may be more responsive to functional differences in children's performance. Test analysis should reveal the implicit cognitive processes embedded in items and to describe student achievement in terms of efficiency and accuracy of process execution; furthermore, test data analysis should determine the extent to which students use efficient strategies or whether they represent information optimally in any given task of interest. Recent advances in psychological theory of learning and cognition point to the feasibility of such a qualitative approach to test data analysis and interpretation.

Current research approaches use models, concepts and techniques from cognitive psychology to analyze complex performance in intellective tasks and to identify the constituent cognitive processes and strategies in efficient and inefficient learners. This paper reviews the theory and research on the identification and trainibility of cognitive processes with a view towards a reconceptualization of standardized test data analysis that reflects such developments.

Theoretical Perspective

Cognitive theorists, especially those who espouse an information processing perspective of intelligence, propose that in part, the psychological bases of intelligent behavior can be understood in terms of components of information processing (Carroll, 1976; Campione and Brown, 1979; Hunt, 1978; Jensen, 1979; Newell and Simon, 1972; Pellegrino and Glaser, 1979; Snow, 1979; Sternberg, 1977, 1979). Although they consider different components to account for the latent abilities that underlie intelligent behavior, they all view the "component" as the basic unit for understanding individual differences in intelligence. (Sternberg, 1977, 1979), described a "component" as an elementary information process that operates upon an internal representation of objects or symbols. Sternberg's theory of intelligence will serve as the conceptual framework out of which will evolve the information processing model for the analysis of test data.

In his componential theory of intelligence, (Sternberg, 1977, 1979, 1980), subdivides components of intelligence in two ways: by function and by level of generality.

Classification of Components by Function

Five different types of components can be distinguished on the basis of function: Metacomponents- higher-order processes involved in decision making and planning during problem solving and evaluating the success of one's problem solving performance. He considers six metacomponents as of particular importance in any problem solving situation:

(a) defining the nature of the problem
(b) selecting the components or steps needed to solve the problem
(c) selecting a strategy for ordering components of problem solving
(d) selecting a mental representation for information in the problem
(e) allocating resources (setting speed-accuracy tradeoffs in problem solving
(f) monitoring solution.

Performance components- processes used to manipulate and transform information in the actual performance of a task. While processes may differ depending on the nature of the problem, in general, they are organized in four phases of problem execution:

(a) encoding stimuli (storing information in working memory and retrieving information from long term memory that might be potentially relevant for interpreting the stimuli
(b) combining elements into a workable strategy
(c) justifying one option as preferred although not ideal
(f) making a response

Knowledge-acquisition components. These processes are involved in learning new and contextual information. Knowledge-acquisition related processes store, maintain and retrieve information upon which performance components operate. Examples of these components can be found in reading comprehension passages which require an individual to sift relevant from irrelevant information, combine disparate pieces of information into a meaningful integrated whole or to compare old and new information in figuring the meaning of a word.

Classification of components by level of generality

Three different types of components: general, class and specific can be distinguished on the basis of generality. General components are those processes involved in the execution of all tasks common to a universe of tasks under consideration. A metacomponent such as defining the nature of the problem and a performance component as encoding constitute examples of general components on an aptitude test. Class components are those processes involved in a subset of tasks nested within a broader task universe. Consider for example, the subset of verbal inductive reasoning tasks found on any Scholastic Aptitude Test. Inference- a process used in finding the relationship between the first two terms of an analogy and application - the process used in carrying over the inferred relation to the last two terms of the analogy to establish an ideal solution, would constitute class components. Specific components are those unique processes involved in the execution of single tasks within any given task universe.

The different types of components and their level of generality are theorized to be closely interrelated. For those components distinguished on the basis of function, metacomponents assume a pivotal role in an integrated intelligent system. Only metacomponents can directly activate and receive feedback from other types of components; while other components can activate and also receive feedback from each other, they do so only through the mediational filters of the metacomponents. For components distinguished on the level of generality, the pattern of interrelations will depend on the breadth of the universe of tasks under consideration. A process considered a general component in the universe of verbal inductive reasoning tasks might be a class component in the universe of both verbal inductive reasong and spatial visualization tasks.

Cognitive process research

Within the last decade, numerous studies have sought to identify the existence of these processes through the analysis of successful task performance on a variety of complex tasks. With respect to performance components, Sternberg (1977a, 1977b; Sternberg and Gardner, 1982,1983; Sternberg and Nigro, 1980; Sternberg and Rifkin, 1979) identified seven processes which underlie successful solution of verbal analogies. In many investigations, these processes - encoding, inferring, mapping, applying, justifying and responding - have accounted for variability in subjects' response latencies and error rates. Similar findings on geometric , number and verbal analogical reasoning tasks were reported by Pellegrino and Glaser (1982). Different types of performance components have also been identified in reading performance (Hunt, Lunneborg & Lewis, 1975; Jackson & McClelland, 1979; Perfetti & Lesgold, 1977; and Scarborough, 1977), problem solving in geometry (Greeno, 1978) and Physics (Larkin, 1981).

The identification of metacomponents has also been investigated in a variety of tasks. In one of their analogies studies, (Sternberg & Gardner, 1983) isolated metacomponents related to planning. In another analogies study, (Sternberg & Rifkin, 1979) found that better reasoners tend to spend a longer time in encoding terms of an analogy than do poor reasoners. In yet another study, (Sternberg and Rifkin, 1982) it was found that older children tended to perform the processes of analogical reasoning more exhaustively than do younger children. Other metacomponential processes have been addresses in studies of verbal comprehension as well. Examples of metacomponential processes so studied include: deciding on the nature of the problem in reading comprehension (e.g., Just & Carpenter, 1980; Anderson & Biddle, 1975), deciding on processes for solving a problem in reading (Frederiksen, 1980; Kintsch & van Dijk, 1978), deciding on how to make a mental representation of information (e.g., Anderson, 1976; Keil, 1979; McNamara & Sternberg, 1983; Sternberg & McNamara, 1985) and solution monitoring (Collins & Smith, 1982).

The findings from these studies have led to further investigations on the trainibility of these processes in both laboratory and applied settings and in a variety of domains. Although the durability and generalizability of training remain problematic in some areas, impressive training outcomes have been reported in reasoning and problem solving (Feuerstein, 1979) Holzman, Glaser & Pellegrino, 1976; Linn, 1973; Sternberg, Ketron & Powell, 1982), and memory (Belmont & Butterfield, 1971; Brown & Campione, 1977; Wanschura & Borkowski, 1975).

To summarize, as the research reviewd showed, different types of information processing components do underlie performance on complex tasks and in many instances do provide a good account of the variability in subjects' response latencies and error rates. Analysis of behavior in terms of cognitive constructs can yield a wealth of diagnostic and pedagogic information to an examiner. A review of latency scores and error data can pinpoint the source/s of an individual's strengths and weaknesses in a way that would lead to a prescription for remedying an observed deficiency or capitalizing on an observed strength. Furthermore, componential analysis can reveal the extent to which processes are executed efficiently or whether they are inaccessible or unavailable to the individual. Finally, process analysis can specify whether such an individual uses an inefficient strategy in problem solving or whether an individual mentally represented the problem in a suboptimal manner. Thus, a model stemming from such an analysis of human behavior might be conceptualized in terms of the following stimulus and person characteristics :- (a) type of components; (b) level of components; (c) type of information content (e.g., numerical, geometric or verbal); (d) type of strategy; (e) form of mental representation on which strategy and component operate.

Componential analysis of standardized tests

Given our understanding of the process dimensions underlying intellectual tasks, how might such information be used to improve the state of the art of standardized tests?. In our own work, we have begun to unbundle the process dimensions that seem embedded in items on standardized tests in science and mathematics; more recently, we have used a componential analytic technique to design teacher made tests and to analyze examinee's behavior in an intellectual enhancement program for high school students. In a related field, Sternberg and his associates are currently working on a test of intellect based on his conceptions of intelligence. The claim made here is that information processing constructs should guide both item construction and analysis of examinee behavior. On a hypothetical standardized test for example, an information processing perspective might seek answers to the following questions related to item construction:

(1) What are the task domains or content areas for which items were written?
(2) Under which factorial categories might items fall and in which item response might cluster empirically?
(3) Into what forms of representation are items written and how might they be classified functionally?
(4) What are the task levels for each item on the test?
(5) What level/s of process might be required for items within each task level?
(6) What type of process/es might each item require for successful task performance?

In assessing student outcomes in terms of information processing constructs, the following questions might also be addressed on the hypothetical standardized test:

(1) What component processes were used on each test item?
(2) On what internal representation/s did such processes operate?
(3) Into what strategy or strategies did different components combine?
(4) How consistent was the use of strategies by individual students?
(5) What was the quality of response time per item?
(6) What was the quality of response time per component?
(7) How might student errors be characterized?

Satisfactory answers to these questions on item construction and student performance would go a long way in enabling us to better understand the nature and demand of tests and the nature and behavior of examinees. Such a focus would guide the design of tests that are sensitive to individual differences in a way that traditional tests are not.

A long standing complaint against standardized tests is that they reflect an overly selective view of achievement and are dysfunctional and counterproductive to the purposes of pedagogy (Glaser, 1977, Gordon, 1977). As these critics have argued, this is true of their use with all children; but when we use them to assess achievement of the poor, disadvantaged and the discriminated against, the problem is compounded. Fortunately, we have come to recognize that individuals differ in the efficacy with which they process, strategize and mentally represent information and test design and analysis of tests should be more responsive to these functional characteristics of human behavior. Until now, inadequate attention was given to these concerns. Hopefully, the theoretical insights and empirical data from cognitive science may be used to guide the qualitative analysis of tests and test-takers' behavior and may lead to the development of tests that would enable us to diagnose and eventually remedy deficiencies in observed behavior. At the present time the cost to develop these tests or the time to administer them is prohibitive and therefore not practically feasible. But the technical feasibility has already been demonstrated in laboratory investigations and it would indeed be a red letter day for education and the testing industry when such develomements are considered to be economically feasible.

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