Cognition and Intelligence

In 1957, Lee Cronbach called on the membership of the American Psychological Association to bring together experimental and differential approaches to the study of cognition. The field of intelligence research is an example of a response to that call, and *Cognition and Intelligence: Identifying the Mechanisms of the Mind* investigates the progress of this research program in the literature of the past several decades. With contributions from formative experts in the field, including Earl Hunt and Robert Sternberg, this volume reviews the research on the study of intelligence from diverse cognitive approaches, from the most bottom-up to the most top-down. The authors present their findings on the underlying cognitive aspects of intelligence based on their studies of neuroscience, reaction time, artificial intelligence, problem solving, metacognition, and development. The book summarizes and synthesizes the literature reviewed and makes recommendations for the pursuit of future research in the field.

Robert J. Sternberg is IBM Professor of Psychology and Education at Yale, Director of the PACE Center at Yale, and 2003 President of the American Psychological Association. He is the author of more than 1,000 publications on topics related to cognition and intelligence and has received over $18 million in grants for his research. He has won numerous awards from professional associations and holds five honorary doctorates.

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Cognition and Intelligence

Identifying the Mechanisms of the Mind

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Preface

COGNITION AND INTELLIGENCE

How did the study of cognition and intelligence get started? Although some psychologists in the nineteenth century were interested in cognitive processing (e.g., Donders, 1868/1869), the connection between information processing and intelligence seems first to have been explicitly drawn by Charles Spearman (1923), the same individual known for initiating serious psychometric theorizing about intelligence with his theory of the general factor of intelligence (Spearman, 1927).

Spearman (1923) proposed what he believed to be three fundamental qualitative principles of cognition. The first, *apprehension of experience*, is what today might be called the encoding of stimuli (see Sternberg, 1977). It involves perceiving the stimuli and their properties. The second principle, *eduction of relations*, is what today might be labeled inference. It is the inferring of a relation between two or more concepts. The third principle, *eduction of correlates*, is what today might be called application. It is the application of an inferred rule to a new situation.

Spearman was not the only early psychologist interested in the relationship between cognition and intelligence. Thorndike et al. (1926) proposed a quite similar theory based on Thorndike's theory of learning. According to this theory, learned connections are what underlie individual differences in intelligence. Some early researchers tried to integrate cognition and biology in studying intelligence. For example, the Russian psychologist Alexander Luria (1973, 1980) believed that the brain is a highly differentiated system whose parts are responsible for different aspects of a unified whole. In other words, separate cortical regions act together to produce thoughts and actions of various kinds. Luria (1980) suggested that the brain comprises three main units. The first, a unit of arousal, contains the brain stem and midbrain structures, including the medulla, reticular activating system, pons, thalamus, and hypothalamus. The second unit of the brain is a

sensori-input unit, which comprises the temporal, parietal, and occipital lobes. The third unit is the frontal cortex, which is involved in organization and planning. It comprises cortical structures anterior to the central sulcus. Luria's theory remains of interest to researchers even today (Naglieri & Das, 1990, 1997).

In general, early approaches to cognition and intelligence came in fits and starts. Lee Cronbach (1957) tried to revive interest in the cognitive approach with an article on "the two disciplines of scientific psychology," and there were some fits and starts during the 1960s in an effort to revive this approach. But systematic work was to wait until the 1970s.

Serious revival can probably be credited in large part to the work of Earl Hunt (1978, 1980; Hunt, Frost, & Lunneborg, 1973; Hunt, Lunneborg, & Lewis, 1975), who was the originator of what has come to be called the cognitive-correlates approach to integrating the study of cognitive processing with the study of intelligence (Pellegrino & Glaser, 1979). It examined basic (sometimes called "lower order") processes of intelligence.

The proximal goal of this research is to estimate parameters representing the durations of performance for information processing components constituting experimental tasks commonly used in the laboratories of cognitive psychologists. These parameters are then used to investigate the extent to which cognitive components correlate across participants with each other and with scores on psychometric measures commonly believed to measure intelligence, such as the Raven Progressive Matrices tests.

For example, Hunt and his colleagues used the Posner and Mitchell (1967) task as one of their cognitive tasks. This task requires individuals to recognize whether two letters match physically or (in another variant of the task) in name. The goal of such a task is to estimate the amount of time a given participant takes to access lexical information – letter names – in memory. The physical-match condition is included to subtract out (control for) sheer time to perceive the letters and respond to questions. The difference between name and physical-match times thus provides the parameter estimate of interest for the task. Hunt and his colleagues found that this parameter and similar parameters in other experimental tasks typically correlate about −.3 with scores on psychometric tests of verbal ability.

The precise tasks used in such research have varied. The letter-matching task has been a particularly popular one, as has been the short-term memory scanning task originally proposed by S. Sternberg (1969). Other researchers have preferred simple and choice reaction time tasks (e.g., Jensen, 1979, 1982). Most such studies have been conducted with adults, but some have been conducted developmentally with children of various ages (e.g., Keating & Bobbitt, 1978).

An alternative approach came to be called the cognitive-components approach (Pellegrino & Glaser, 1979). This approach focused on higher-order components of intelligence. In this approach, participants are tested on

their ability to perform tasks of the kinds actually found on standard psychometric tests of mental abilities – for example, analogies, series completions, mental rotations, and syllogisms. Participants typically are timed and response time is the principal dependent variable, with error rate and pattern-of-response choices serving as further dependent variables. This approach was suggested by Sternberg (1977; see also Royer, 1971).

The proximal goal in this research is, first, to formulate a model of information processing in performance on the types of tasks found in conventional psychometric tests of intelligence. Second, it is to test the model while estimating parameters for the model. Finally, it is to investigate the extent to which these components correlate across participants with each other and with scores on standard psychometric tests. Because the tasks that are analyzed are usually taken directly from psychometric tests of intelligence or are very similar to such tasks, the major issue in this kind of research is not whether there is any correlation at all between cognitive task and psychometric test scores. Rather, the issue is one of isolating the locus or loci of the correlations that are obtained. One seeks to discover what components of information processing are the critical ones from the standpoint of the theory of intelligence (Carroll, 1981; Pellegrino & Glaser, 1979, 1980, 1982; Royer, 1971; Sternberg, 1977, 1980, 1983; Sternberg & Gardner, 1983). An example of a component would be inference, which refers to the conceiving of a relationship between two items (such as words, numbers, or pictures).

Thus, Hunt and his successors focused on lower-order processes, whereas Sternberg and his successors focused on higher-order processes. A third approach focused on developmental processes. Jean Piaget (1952, 1972) was never very interested in individual differences. He viewed intelligence as arising from cognitive schemas, or structures that mature as a function of the interaction of the organism with the environment. Piaget (1926, 1928, 1952, 1972), like many other theorists of intelligence, recognized the importance of adaptation to intelligence. Indeed, he believed adaptation to be its most important principle. In adaptation, individuals learn from the environment and learn to address the changes in the environment. Adjustment consists of two complementary processes: assimilation and accommodation. *Assimilation* is the process of absorbing new information and fitting it into an already existing cognitive structure about what the world is like. The complementary process, *accommodation*, involves forming a new cognitive structure in order to understand information. In other words, if no existing cognitive structure seems adequate to understand new information, a new cognitive structure must be formed through the accommodation process.

The complementary processes of assimilation and accommodation, taken together in an interaction, constitute what Piaget referred to as equilibration. *Equilibration* is the balancing of the two and it is through this

balance that people either add to old schemas or form new ones. A *schema*, for Piaget, is a mental image or action pattern. It is essentially a way of organizing sensory information. For example, we have schemas for going to the bank, riding a bicycle, eating a meal, visiting a doctor's office, and the like. Equilibration unfolds through four stages of cognitive development: sensori-motor, preoperational, concrete-operational, and formal-operational.

Whereas Piaget emphasized primarily biological maturation in the development of intelligence, other theorists interested in structures, such as Vygotsky (1978), emphasized more the role of interactions of individuals with the environment. Vygotsky suggested that basic to intelligence is *internalization*, which is the internal reconstruction of an external operation. The basic notion is that we observe those in the social environment around us acting in certain ways and we internalize their actions so that they become a part of us.

Vygotsky also proposed the important notion of a *zone of proximal development*, which refers to functions that have not yet matured but are in the process of maturation. The basic idea is to look not only at developed abilities but also at abilities that are developing. This zone is often measured as the difference between performance before and after instruction. Thus, instruction is given at the time of testing to measure the individual's ability to learn in the testing environment (Brown & French, 1979; Grigorenko & Sternberg, 1998; Feuerstein, 1980). The research suggests that tests of the zone of proximal development tap abilities not measured by conventional tests.

By the 1980s, it was clear that there were *many* ways in which intelligence could be examined through cognitive means. Many of these are summarized in various handbooks of intelligence (Sternberg, 1982, 2000) as well as an encyclopedia of intelligence (Sternberg, 1994). The field has progressed by leaps and bounds since the work in the 1970s and 1980s, and the goal of this volume is to document that progress, concentrating particularly on research that is ongoing or that has been conducted in the last 10 years.

The organization of this book is in terms of the three main approaches described here. Within these approaches, there are diverse points of view. One approach looks at biological and basic processes. A second looks at higher-order processes. And a third concentrates on developmental processes. Students of intelligence will find all three approaches represented here.

This book is written for upper division undergraduate students, graduate students, career professionals, and anyone else who wishes to understand the current landscape with respect to the study of cognition and intelligence. The book contains chapters by many of the leading contemporary figures in this field.

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