have much value. If he does accept the challenge, he may have to move beyond the halfway measures of the current theory and create an entirely new paradigm for cognitive research. The task is worthwhile, but it will certainly require more precision in definition of constructs, specification of levels of analysis, and articulation of relationships among theory components than is characteristic of this article.

Mental speed and levels of analysis

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Sternberg's impressive attempt to synthesize and systematize much of the broad spectrum of behavioral phenomena associated with the concept of intelligence deserves admiration. Considerable beneficial effects on the advancement of a science of human ability are bound to stem from this effort. While it is still taking shape in Sternberg's programmatic research, however, it might prove helpful to point out one facet of the present formulation that, in my opinion, is most in need of rethinking and more sophisticated analysis. I refer to Sternberg's treatment of "mental speed." I use quotation marks, because the meaning of the term depends on our level of analysis. When this is not explicitly specified, only confusion and misunderstanding on this topic will prevail.

Sternberg's treatment of "mental speed" is confusing because it fails to distinguish clearly between speed at the level of the most elementary or basic cognitive processes that underlie intelligence and at the level of complex behavioral manifestations of intelligence. We are confronted by such seeming paradoxes, for example, as the popular notion that "smart is fast" (to use Sternberg's words), and that "quick-witted" persons are commonly seen as bright, although a number of the world's undisputed geniuses have been described by themselves or by their closest associates as "slow thinkers" – Darwin and Einstein, for example, and Beethoven, for whom composing was a slow, laborious struggle as compared with, say, the quick facility of Rossini.

Yet, in performance of various simple and choice reaction-time tasks, we find positive correlations between individual differences in speed of reaction and scores on traditional tests of intelligence and scholastic achievement (Carlson & Jensen 1982; Jensen 1982a; 1982b). Various criterion groups show reaction times on extremely simple tasks involving only the most elemental aspects of information processing, which, on average, are perfectly in accord with the groups' levels of general intelligence, as this concept is commonly understood. University students show faster reaction time (RT) than vocational college students, who are in turn faster than unskilled factory workers, who are faster than the mentally retarded (Jensen 1979; 1980b; Jensen, Schafer & Crinella 1981; Sen, Jensen, Sen & Arora 1983; Vernon 1981; 1983).

On the other hand, when the task is something as complex as solving relatively difficult reasoning problems, such as the items in Raven's Progressive Matrices, the correlation between individual differences in average response latency to the test items and psychometric intelligence (as measured by the total number of items gotten right on the Raven or any other standard intelligence test) vanishes completely, as I have noted elsewhere (Jensen 1980b; 1982b). On the other hand, if we obtain the mean latency (i.e., averaged over subjects) for each item, we find that there is a virtually perfect rank-order correlation between item latency and item difficulty as measured by the percentage of subjects who select a wrong answer. That is, more difficult items require more time for correct solution. I have termed this phenomenon the *test-speed paradox* – the seeming paradox being the fact that (a) average response latency is directly related to item difficulty and (b) individual differences in the speed of executing relatively elementary cognitive processes are correlated with psychometric intelligence, whereas (c) the speed of solving much more complex problems is correlated little, if at all, with psychometric intelligence. I do not believe that the latter fact (c) can be used to contradict or denigrate the importance of the former fact (b) for understanding the nature of intelligence. I have discussed this "paradox" in detail and suggested a possible explanation elsewhere (Jensen 1982b). The phenomena (a), (b), and (c) are not theoretically incompatible when each is explained at a different level of analysis in the hierarchy of information-processing components, ranging from the lowest, most elemental processes to the complex coordination of multiple processes or metacomponents. It is theoretically possible, and, I think, likely, that the underlying mechanisms of general intelligence are essentially simpler than their manifestations in complex problem solving and other "real-life" behavior.

In my view, several well-established concepts and principles of cognitive psychology provide a rationale for the importance of a time element in mental efficiency. The first such concept is that the conscious brain acts as a one-channel or *limited capacity* information-processing system. It can deal simultaneously with only a very limited amount of information; the limited capacity also restricts the number of operations that can be performed simultaneously on the information that enters the system from external stimuli or from retrieval of information stored in short-term or long-term memory (STM or LTM). Speediness of mental operations is advantageous in that more operations per unit of time can be executed without overloading the system. Second, there is *rapid decay* of stimulus traces and information, so that there is an advantage to speediness of any operations that must be performed on the information while it is still available. Third, to compensate for limited capacity and rapid decay of incoming information, the individual resorts to *rehearsal and storage* of the information into intermediate or long-term memory, which has relatively unlimited capacity. But the process of storing information in LTM itself takes time and therefore uses up channel capacity, so there is a "trade-off" between the storage and the processing of incoming information. [See also Broadbent: "The Maltese Cross," *BBS* 7(1) 1984.] The more complex the information and the operations required on it, the more time that is necessary, and consequently the greater the advantage of speediness in all the elemental processes involved. Loss of information due to overload interference and decay of traces that were inadequately encoded or rehearsed for storage or retrieval from LTM results in "breakdown" and failure to grasp all the essential relationships among the elements of a complex problem needed for its solution. Speediness of information processing should therefore be increasingly related to success in dealing with cognitive tasks to the extent that their information load strains the individual's limited channel capacity. The most discriminating test items would thus be those that "threaten" the information-processing system at the threshold of "breakdown." In a series of items of graded complexity, this "breakdown" would occur at different points for various individuals. If individual differences in the speed of the elemental components of information processing could be measured in tasks that are so simple as to rule out "breakdown" failure, as in the various RT paradigms we have used, it should be possible to predict individual differences in the point of "breakdown" for more complex tasks. This is the likely basis for the observed correlations between RT variables measured in relatively simple tasks and total scores on complex g-loaded tests. Most of Sternberg's research and thinking has been focused on a different level of analysis, higher in the hierarchy of complexity of information processing and closer to the behavioral expression of intelligence than the more elementary level of information processing on which I, Earl Hunt (1978), and others have focused our attention.

I have suggested, in fact, that even individual differences in the speed of elemental information processing may not be the most basic source of individual differences in intelligence but may be only a secondary phenomenon, derived from a still more basic source of individual differences – a hypothetical construct I have termed "neural oscillation," which would account for individual differences in intertrial variation in RT as well as in individual differences in RT averaged over a given number of trials (Jensen 1982b). Eysenck (1982) also regards differences in mental speed and RT as derivative, in the sense that a person's average RT is not directly attributable to the speed of neural conduction or synaptic transmission. He hypothesizes that speed differences arise from individual differences in the rate at which errors occur in the transmission of neural impulses in the cortex. The stimulus message must persist until the "pulse train" of neural impulses exceeds a certain fidelity threshold. The more random "noise" or error tendency in the neural system, the more time this takes, and hence speed of reaction is a derivative phenomenon.

Sternberg's postulated components still bear a bit too much resemblance to autonomous homunculi, or "ghosts in the machine," to be entirely comfortable for me, from a natural science standpoint. (This seems a rather general characteristic of cognitive psychology at present.) But even assuming that the componential theory is essentially correct, Sternberg will sooner or later have to confront the question of what governs individual differences in the speed or efficiency with which his "homunculi" operate. There is a large general factor even among the different elementary processing components, that is, they are intercorrelated. Why? Is this fact not the real crux of explaining individual differences in psychometric *g* and all its correlates?

It appears to me that one of the differences between Sternberg's approach and mine is that he is working from the top down, *whereas I am working from the bottom up, so to speak.* I am trying to determine how much of the variance in psychometric *g* can be accounted for purely in terms of the speed of execution of a limited number of the most elemental cognitive processes. It already appears that something approaching half the total variance in *g* can be accounted for in terms of individual differences in RT (and its associated intraindividual variability) to a few elementary cognitive tasks, and it is possible that further exploration will raise the "explained" variance even higher, perhaps to three-quarters, or more, of the total reliable variance in psychometric *g*. Unlike Sternberg, moreover, I do not believe that more than a tiny fraction, if any, of the variance in *g* accounted for by RT is attributable to "time-pressure" or "speediness" factors in the psychometric tests. The evidence clearly contradicts this notion that RT is correlated with psychometric intelligence because some IQ tests are given with a time limit. Timed and untimed tests show the same correlation with RT. If it turns out that a large proportion of the variance in psychometric *g* is explained by the elementary cognitive processes reflected in RT measurements, what will be left over for Sternberg's metacomponents to account for, unless it is mainly the "real-life" manifestations of *g* in educational and occupational achievements? But that is a worthwhile enterprise, too, of course, because the imperfect correlation between *g* and achievement is itself in need of more exact explanations than we now possess.

In what sense does intelligence underlie an intelligent performance?

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What can one say? If one attempts to detail all of the factors ranging from social structures to local situation to specific tasks on the one hand, and to prior knowledge, available processes, and strategies on the other, and to constraints such as novelty and adaptiveness on a third – should one have a third – one would end up with an omnibus theory of intelligence of the sort that Sternberg has competently assembled. Although the increase in variables increases the scope of the theory, it offers little advance in our understanding of intelligent action. What is needed is a new concept of intelligence.

The fundamental assumption that Sternberg, unlike Piaget, for example, never seriously examines – except to adopt it – is that "intelligence" is a personal quality of mind, a trait, which differs importantly from individual to individual, which is prior to and independent of experience, learning, and achievement, and which thereby causes and explains variation in human competence. It consists, he says, of "the *ability* to deal with novel . . . demands" and "the *ability* to automatize information processing" [emphasis added]. Thus, although the vehicles by means of which one measures these "abilities" will need to differ across social groups, the underlying mechanisms to be measured and their functioning are common to all groups. A theory of intelligence, Sternberg says, is concerned with how individuals vary not in their mechanisms and functions, for these are universal, but in their *abilities* with these mechanisms and functions. Thus, intelligent people have more ability to automatize procedures and to deal with novelty. Again, intelligence explains intelligent performances: it is a quality of mind, the quantity of which differs from individual to individual, that explains differences in performance. And, of course, once one makes that assumption, the race is on to find the best technique for getting at that variability. Some experimenters try choice-reaction times; some try timing retrieval from memory: some, like Sternberg, try analogy problems, and so on. But the as*sumption that there is something about the quality of the mind* that basically, and perhaps genetically, varies from person to person is uncontested ground. That assumption, although commonsensical, is in my view the major weakness of the theory.

There is an alternative possibility. Piaget thought that the search for intelligence as quality of mind was a block to understanding intelligence rather than a means to that understanding. He viewed intelligence as systems of schemes or structures of mind people use to do things. Although intelligence presupposes biological structures and an environment in which to operate, it was for Piaget intrinsically interactive. There is no basic quality of mind postulated to explain the degree to which one benefited from experience in becoming competent. Intelligence was simply the assembly of mental structures used in coping with the physical and social world, and that intelligence develops through a series of quite fundamental reorganizations of cognitive structure. Intelligence is the set of structures for doing things; it is not something that underlies or makes possible the acquisition of those structures. Put another way, intelligence is not the ability to reorganize cognitive structure, but it is those reorganized cognitive structures in themselves; it is not the *ability* to assimilate and accommodate, but it is assimilation and accommodation per se; it is not the ability to automatize (restructure) procedures, but it is those automatized procedures in themselves.

Let me try to make the point a different way. Sternberg approvingly cites Hunt's (1978) and Keating and Bobbitt's (1978) claim that "individual differences in intelligence can be understood . . . in terms of differences among individuals in speed of access to lexical information stored in long-term memory." For Sternberg, as for Hunt and Keating and Bobbitt, speed of access is fast for some individuals *because* they are intelligent. They have the ability to automatize procedures, Sternberg might add. There is no question that people differ in the speed of lexical access or in the degree of automatization, or, for that matter, in anything else. But, and here is the crucial question, is that speed the result of being intelligent, or is it a sample of a competently performed activity? I would think that it is the latter. And it is