INTELLIGENCE, 6, 99–108 (1982)

Does "g" Exist?*

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Is the nature of intelligence best understood as a single thing ("g"), or as a set of orthogonal variables? It is argued that a set of orthogonal variables is most likely to explain intelligence. Higher-order constructs like Metacomponents, Executive Functioning and "g" are suggested to inevitably result from complex systems having interrelated parts. While such constructs may provide indices of the efficiency of such systems, they do not explain how the systems function. Further, neither parsimony, the pervasiveness of such constructs, nor biological reductionism provide adequate justification for invoking higher-order constructs as explanations of intellectual functioning.

One of the most consistently debated topics in intelligence research has been the degree to which variability in mental tasks can be accounted for on the basis of a single variable, or requires multiple variables for its explanation. This argument has appeared not only in the well-known psychometric controversy over "g" versus multiple orthogonal factor models but, more recently, in cognitive models postulating Executive Functions or Metacomponents. In this editorial, it is argued that single factor explanations of intellectual functioning are unlikely to be adequate.

Before presenting the arguments for this position, it should be made clear what I am not arguing. I am not arguing that "g" and similar constructs are completely useless. That would be an unreasonable position. There is overwhelming evidence that such general sources of variance are highly predictive of intellectual behaviors. It is also clear, at least to me, that concepts like "g" encapsulate the sources of variance that most clearly define intelligence.

What I will consider is how "g" and concepts like it might best be explained. Are such concepts best thought of as a single thing or as a complex of independent factors? This argument has no bearing on the demonstrated practical importance of such concepts or on the usefulness of the tests and tasks upon which the concepts are based. The argument to be presented is only relevant to understanding why such concepts are practically useful. Differing opinions about what might constitute the best explanation of an empirical phenomenon do not justify dis-

*Preparation of this manuscript was partially supported by grants HD-07176 and HD-15518 from the National Institute of Child Health and Human Development.

counting the empirical facts. Because something is not understood does not mean that it does not exist or that the empirical relationships which have been demonstrated are invalid. Arguments which follow such lines of reasoning are unrealistic.

The history of this debate begins well before Spearman and, as with all debates, goes back at least to Aristotle. Aristotle was perhaps the first to propose a general intellective factor. *Nous,* corresponding to intellect or reason, was found only in humans in addition to a motive and vegetative soul found within all animals and all living things, respectively. Thus, Aristotle postulated a single source to explain the differences between man and all other animals.

The first mention of a multifactor theory seems to be by Juan Huarte (1530–1589) who was a classically trained Spanish physician. His book (Huarte, 1698), *The Tryal of Wits, Discovering the Great Difference of Wits Among Men and What Sorts of Learning Suits Best with Each Genius,* was quite popular for its time, went through several printings, and was translated into several other languages.

Huarte's theory was heavily influenced by humoral theories. Memory was influenced by moisture, imagination by heat, and understanding by dryness and coolness. Differences in climate were, therefore, important in explaining differences in national character. Huarte also suggested that there were a number of independently distributed aptitudes which interacted with training. He was not only the first to suggest a multifactorial model but also the first to describe aptitude by treatment interactions. The following quote summarizes Huarte's arguments:

> . . . for if thy wit be of the common and vulgar alloy, I know right well thou art alreadie persuaded, that the number of the sciences, and their perfection, hath been accomplished many daies agoe. And hereto thou art moved by a vaine reason, that they having found out no more what to ad, it is a token, that now there is nothing, any more novelties. Now if by hap thou art possessed of such an opinion, go no further, nor read thou anie longer on for thou wilt be much agreeved, to see how miserable a difference of wit possesseth thee. But if thou be discreet, well compounded, and sufferent, I will deliver unto thee 3 conclusions very true, albeit for their noveltie they are worthie of great marvell.
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> The first is, that of many differences of wit, which are in mankind, only one with preheminence can fall to thy lot, if alreadie, nature, as verie mightie, at such time as she framed it for thee, did not bestow all her endevour, in uniting two onely, or three, or (in that she could not effect the same) left the a dolt, and deprived of them all.
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> The second, that to every difference of witt there answereth in preheminence, but only one science, and no more of that condition. So as if thou divine not to chuse that which answereth thy naturall ability, thou shalt be very remisse in the rest, though they ply them night and day.
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> The third, that after thou hast known which the science is, that most answereth thy wit, there resteth yet (that thou mayst not be deceived) another greater difficultie, which is, whether thine abilities be more applicable to the practick than the theorick, for these 2 parts (be it what science it wil) are so opposit betwixt themselves, and require wits so different, that they may be placed one against the other, as if they were contraries. Hard are these sentences, but yet they have greater difficultie and hardness, vz. that we cannot appeale from them, nor pretend that we have received wrong. (No page number)

Much of what Huarte says sounds strikingly modern. Indeed, his theory contains many of the aspects of current multifactorial models. Though most would regard the debate between multifactor and single factor models as a recent one, the basic ideas inherent in this debate have been around for some time.

RECENT HISTORY

The modern history of this issue spans only this century, and begins with Spearman (1904). He noted that mental tests having substantially different forms were intercorrelated. This suggested to him that there was a common factor accounting for performance on these tests. To test this observation, he developed the Method of Tetrad Differences—a method for extracting the correlations between tests and the common factor. The Method of Tetrad Differences laid the foundation for modern factor analysis. It also supported Spearman's initial observation of a common factor, but not completely. In some cases, the general factor did not account for all of the test's variance, and so specific and group factors had to be added to complete the analysis.

Thurstone (1938) proceeded from a completely different framework than Spearman. He assumed that human intellectual abilities were better resolved into a small number of independent factors, and devised a set of criteria that would do that. His analyses resulted in the Primary Mental Abilities. However, it was not long before it was pointed out (Cattell, 1971, p. 25) that the factors representing these abilities were, themselves, intercorrelated suggesting the presence of a general factor.

Cattell (1971) attempted to resolve the differences by postulating a well-worked out hierarchical factor theory in which general factors played an important part, but which also included more specific abilities as lower-order factors. On the other hand, Guilford (1967) presented his Structure of Intellect model, postulating 120 independent factors representative of intellectual functioning. However, more recently (Guilford, 1980), the independence of factors assumption seems to have been relaxed. Evidently, the conclusion that there is a general intellective factor is inescapable, at least from the history of factor-analytic research and theory.

The same trend would seem to be appearing in cognitive research. A good example is the work of Jensen (1979) who used psychometric "g" as defined by factor analysis to find experimental tasks which were good predictors of intellectual functioning. There are also far more subtle examples of the same trend, two of which will now be presented.

The first example comes from mental retardation research. Ellis (1970) presented a model of memory along with substantial data to indicate that mentally retarded subjects were deficient in rehearsal—a process postulated to maintain material in primary memory and move it to longer-term stores. Belmont and Butterfield (e.g., 1982) suggested that the memory deficit which had been localized by Ellis was simply a specific example of a strategy deficit. They suggested that the primary difference between persons of normal intelligence and the mentally retarded was the degree to which they could develop and use information-processing strategies. And indeed, other investigators had located deficits in almost every part of the model suggested by Ellis (Detterman, 1979).

Belmont and Butterfield postulated a process called Executive Functioning which controlled the strategies used to control the flow of information through the system. Since the effects of Executive Functioning were systemic, it is not surprising that deficits could be demonstrated in every part of the system. Executive Functioning is analogous to the general intelligence factor since its effects should be evident in every sort of mental test or cognitive task given.

A second example can be found in the work of Sternberg (1979). He proposed a method of analysis called Componential Analysis which consisted of decomposing a test into its components by devising subtests to measure each postulated component. It was hoped that the components isolated in this fashion would be independent and additive contributors to test performance. However, some of the components were intercorrelated. To account for this finding, Sternberg postulated Metacomponents which are similar to Executive Functioning suggested by Belmont and Butterfield. Like Executive Functioning, Metacomponents are viewed as having systemic effects.

Not only have factors representing general sources of variation been found in the psychometric and cognitive domains, but similar concepts have been suggested at the biological level. Lashley's conception of mass action and equipotentiality is very similar to "g," and may be contrasted to theories of localization of function. Indeed, Lashley's history of his search for the engram is reminiscent of the history of factor analysis.

There are, however, theories which propose multiple orthogonal variables as determinants of intellectual behavior. A good example is the model presented by Carroll (1980). He suggests 10 independent factors which might account for performance on many cognitive tasks. The variables resulted from a careful factor-analytic consideration of experimental results from Carroll's and others' research.

I have also proposed a model operationalized by a number of independent, uncorrelated variables (Detterman, 1979). This model is actually a modal model representing an integration of a number of other theoretical efforts. At least some of the parameters of this model are known to be independent. The model is shown in Figure 1.

Each box and the relationship between boxes in this model can be defined in terms of three characteristics: capacity, process, and structure. Capacity is the amount of stimulus material (or its mental representation) which can be held in a single part of the system. A process involves the movement or transformation of stimuli or their mental representations. A structure represents the relationship between stimuli or their mental representations. Each part of this model should be represented by a single parameter reflecting the independent contribution of the capacity, process, or structure. If such parameters could be found, then it would

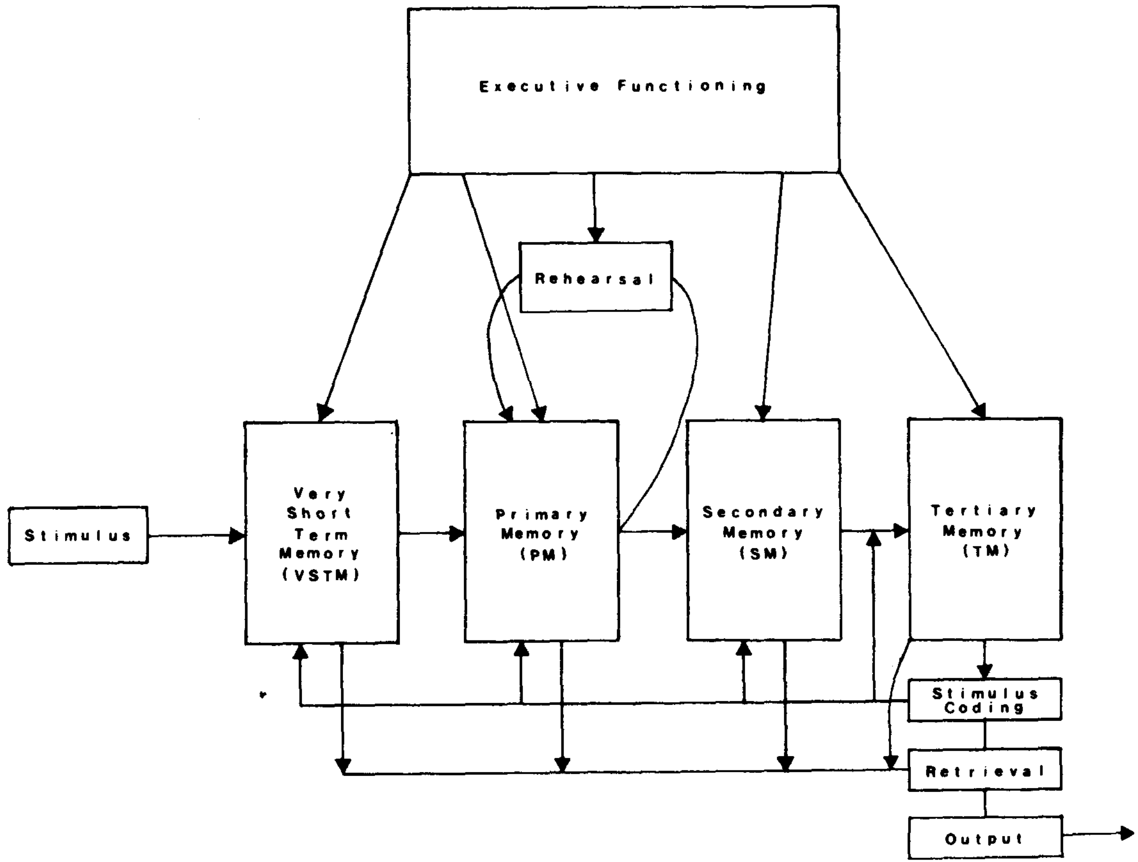

FIG. 1. A model of possible individual differences in information processing.

be possible to represent performance on any mental task as a weighted combination of these basic parameters. The enumeration of the proposed orthogonal parameters of this model would also allow exact modeling of individual differences in the flow of information through the system.

In summary, this brief review of the history of multifactorial and unitary conceptions of intelligence has attempted to show that the debate has a long history. It can be found not only in the factor-analytic literature but also in cognitive models. In fact, the history of cognitive models of intellectual functioning has nearly replicated the history of factor-analytic models. The question to be addressed next is whether either point of view has any logical superiority.

ARGUMENTS FOR "g"

A major argument for "g" (including "g"-like cognitive components) is that it is parsimonious to postulate a single factor rather than multiple factors to account for intellectual functioning. The simplest of explanations is to be preferred. However, "g" is actually a less parsimonious explanation of differences in intellectual functioning than a larger set of independent factors.

General intellectual ability, in its present state of development, is actually a statistical abstraction dependent for its demonstration on a set of mental tests. Although there may be markers for "g," the operational definition of the concept requires multiple tests for its derivation. Thus, though "g" has the potential of parsimony, in its present form it adds theoretical complexity. It is a higher-order construct. The most parsimonious explanation for a set of tests would be to resolve those tests into a smaller number of independent parameters measured independently of the tests, themselves.

Obviously, the smallest number of independent parameters is one and, therefore, "g" should be the most parsimonious of explanations. That would be true if "g" could be demonstrated independently of the test performance we are seeking to explain. That is not the case. Metacomponents, Executive Functioning, and "g" are all higher-order constructs dependent on lower-order constructs for their definition. So long as this is the case, it would seem more parsimonious to attempt explanations in terms of lower-order constructs alone. The addition of higher-order constructs only makes things more complicated.

That "g" is not theoretically parsimonious can best be seen by examining the experimental paradigm most often used to study it. First, a general factor is demonstrated among tests or tasks (in the case of Metacomponents or Executive Functioning). Next, a task is found which correlates highly with this source of common variance. This task may then be used to "explain" the source of common variance. When put in this simple way, it is clear that the logic is circular. What has actually been accomplished is the discovery of another task saturated with the variance common to the tasks used to define the common factor. If the new task had been included in the original analysis, it would have been considered a marker for the common variance, not an explanation of it.

In one sense, the above argument is a straw man. No investigator of "g," Metacomponents, or Executive Functioning could actually be accused of engaging in such a simplistic argument. Indeed, they would more likely argue that the tasks used to explain the general source of variance are derived independently of this general source of variance from theoretical constructs. However, even if this is true, demonstration of the relationship between the explanatory task and the common source of variance depends on the demonstration of the higher-order construct which might be decomposable given satisfactory lower-order constructs.

In short, parsimony is not a good reason for accepting "g," or similar higher-order constructs, as useful. Given the existence of a common source of variance among a set of tasks, there are two alternatives. One is to attempt to devise a set of independent parameters that accounts for the common source of variance. The other is to incorporate the common source of variance into the explanatory theoretical scheme. The former is more parsimonious than the latter, because it involves fewer concepts.

Another argument often used to support the incorporation of constructs representing general sources of variance into theory is the pervasiveness of such sources of variation. Indeed, the historical account presented above would suggest that "g" and "g"-like sources of variation have been found at every bend of the historical road. This is a poor argument.

Since the very beginning of factor analysis, it has been recognized as an exploratory technique. There have been many calls for systematic, programmatic, experimental attempts to explicate the findings from these exploratory methods. Unfortunately, I can think of few, if any, real attempts to answer these calls. It is certainly much easier to modify theory than to modify tests or tasks. These are the two alternatives available when confronted with a pervasive source of common variance. Only the modification and refinement of tests or tasks have the potential of producing independent parameters explanatory of the common source of variance. Certainly, we will not know if such a task can be accomplished until someone makes a serious effort to try it. The distillation of independent parameters explanatory of general sources of variance will certainly be a tedious task, but this is no reason to accept higher-order constructs as more explanatory. Accepting the higher-order explanatory constructs because lower-order constructs have not been demonstrated is a form of inductive logic equivalent to accepting the null hypothesis. Certainly, there are cases where such inductive reasoning is appropriate, but they do not include situations where there have been no concerted attempts to demonstrate the alternative hypothesis.

Another argument sometimes advanced as a justification of "g" is biological. According to this position, "g" and similar constructs result from a single biological characteristic such as neural efficiency, integration, or speed. Such theories are not well-developed and, in fact, can only be considered speculation in their current state. However, even if such relationships between "g" or similar concepts and neural measures were well documented, such relationships would not necessarily offer an explanation of "g." The problem is that such measures, themselves, may have all of the problems that parallel psychological concepts have. Thus, to support the construct to "g" by showing that it is related to another "g"-like biological measure would not be a strong argument.

Biological reductionism for any behavioral phenomenon seems to me to be the least desirable way to explain the behavioral phenomenon. Only dualists would be surprised to find behavioral phenomenon replicated, in some form, at a biological level. In fact, it would be more surprising (and disturbing) to find that "g"-like concepts were not represented at a biological level. The most likely chain of events is that "g"-type, higher-order measures of neural functioning will be the first to be found, thereby replicating the history of behavioral measures.

WHY IS THERE A "g"?

If "g" and "g"-like constructs do not represent a primary explanation of intellectual functioning, why have there been so many of these constructs demonstrated? Why is there a "g" if it is not reflective of some basic aspect of intellectual functioning? These are legitimate questions which surely must be answered by any critic of such concepts.

The only attempt to answer these questions of which I am aware is Thompson's Sampling Theory. According to this theory, intelligence consists of a large set of associative connections. Any task testing intelligence is a sample of these associations. Two tasks are correlated to the extent that they both require the same associative bonds. Accordingly, "g" represents common bonds among all tasks.

Another possible explanation is that, like any complex system, the parts of the system are interrelated and weaker portions of the system set the level of performance for remaining portions. This is perhaps best explained in terms of an anology. A good example of a complex system is a university, although there are many others (Detterman, 1980). There are certainly general indicators of performance of universities. It is unlikely that anyone would deny that universities differ in quality, or that reliable ratings of this general characteristic of quality could be obtained. Neither would they argue that overall ratings of quality are useful for such things as selecting which university to attend. However, few would contend that you could learn much about what makes a good university by studying global ratings. You would certainly want to study more specific factors (faculty, student, or facility quality) to answer that question. In fact, each of these factors could be made quite independent of others, given sufficient resources.

The question is: how do global characteristics of quality result from all of the potentially independent factors that could affect such a system? The answer is that all of the factors are interrelated because they are part of a system. If a university having an outstanding faculty, outstanding students, and outstanding facilities suddenly lost the quality of any one of these three components, the remaining components would very quickly deteriorate. Ratings of global quality would also decline, not because there was a single thing that determined overall quality, but simply because the parts of the system are interrelated and depend on each other for their mutual support.

The same argument can be made for intellectual functioning. Take, as an example, the model presented in Figure 1. Suppose that the assignment of parameters representing the capacities, processes, and structures of this model was initially random. Across individuals, parameters representing this system would be uncorrelated by definition. For purposes of explanation, two parameters will be discussed: the capacity of Primary Memory (PM) and the structure of long-term or Tertiary Memory (TM).

Suppose that the capacity of PM is measured in number of stimulus items, and can range from one to four items. This is the number of items a person can "keep in mind." Assume further that the structure of TM is represented by a hierarchical tree for which the defining parameter is the number of branches possible at each node, which can vary from one to four. The process relating these two aspects of the system are storage and retrieval.

To retrieve an item from TM, a search begins at the top of the tree structure. At each node, the stimulus items representing the distal end of each of the branches are loaded into PM, and each item is evaluated against the target. The search continues with the node represented by the item having the highest similarity (where similarity is defined by the initial criterion of the search) to the target. A search is terminated when similarity reaches some acceptable threshold. Storage is the same process as retrieval, except that the item to be stored is the target and the criterion for success is a literal match or an unfilled node where the item can be stored.

This thumbnail sketch obviously neglects important details which are not crucial to the present discussion. However, it should also be clear that the structure of TM and the capacity of PM are critically interrelated. The very simplest possibility is that if a person has a two-item PM capacity, the tree structure in TM will only have two branches at each node if the assigned value of the TM parameter is two or greater. If it had more branches per node, he would be unable to load all of the items into PM for evaluation during a search. Further, if the structure parameter of TM only supported two items per branch and the capacity of PM were larger, PM capacity would functionally appear to be two items during search, because only one node (two items) of the tree could be loaded into PM at a time.

The simple rule for the interrelationship of these two system characteristics is that the minimum value of PM capacity and TM structure determines the functional value of both. Thus, in practice there would be a substantial correlation between the two parts of the system. More complicated limiting rules could certainly be developed. Such rules would produce complex relationships between parts of the system.

This example has only considered two aspects of a larger system. Since every part of the system is in some way related to every other part, the operation of any part of the system will reflect every other part of the system. Therefore, it must be expected that all parts of the system will be interrelated in operation, though there may be ways to break these correlations, and discover the initially assigned values of each parameter of the system. Obviously, this will be no simple task.

Figure 1 contains a box called Executive Functioning. I would now define this portion of the sytem as the set of limit rules which determine system operating efficiency. It is certainly important to understand these rules, but I do not think it can be done independently of an understanding of the rest of the system. In fact, being able to measure all other portions of the system would seem to be a first priority.

Though "g" and "g"-like constructs have a long and pervasive history of occupying the attention of researchers in intelligence, I believe it is the wrong thing to study, because it is a higher-order characteristic of a complex system. I think it is far more important that we have a good empirical description of the primary parameters of the system first. Only then will we be able to explain the higher-order concepts. If we ignore "g" and its relatives, I think they will go away.

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