Conclusions

The complex down-to-the-basin growth faults of southern Louisiana appear to have been caused by slumping along the edge of the continental shelf during sedimentation. The toes of the slides must resemble low-angle overthrusts, with repetition of section. Although such repetition has never been reported, one may expect to find it in drilling deep, off-shore wells.

The growth faults seal the flow of fluids, and, down-dip from them, abnormally high pressures are found. The shales in these intervals are less compacted than is usual at the depth at which they are buried. The normal processes of compaction and diagenesis were arrested by the faulting. The pore water has remained in the sediments, where it has to support part of the weight of the overburden, and its hydrostatic pressure is, therefore, much above normal. The high pressures show that these shales have extremely low permeability to water, perhaps because their interstitial water is non-Newtonian.

In a few areas, called embayments, the growth faulting caused certain stratigraphic units to be abnormally thick, and the abnormal pressures are found at particularly shallow depths. Salt domes are notably scarce in the embayments, probably because the shales never became dense enough to make the salt rise and form domes.

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Intelligence Has Three Facets

There are numerous intellectual abilities, but they fall neatly into a rational system.

J. P. Guilford

Many a layman who has taken a psychologist's intelligence test, especially if he did not do as well as he thought he should, has the conviction that a score, such as an IQ, does not tell the whole story regarding intelligence. In thinking so, he is absolutely right; traditional intelligence tests fall far short of indicating fully an individual's intellectual status. Just how far short and in what respects have not been well realized until very recent years during which the whole scope of human intelligence has been intensively investigated.

This is not to say that IQ tests are not useful, for they definitely are, as years of experience have demonstrated. Intelligence-quotient tests were originated more than 60 years ago for the purpose of determining which children could not learn at normal rates. This meant that the content of IQ tests weights heavily those intellectual abilities that are pertinent to school learning in the key subjects of reading and arithmetic, and other subjects that depend directly upon them or are of similar nature psychologically. IQ tests (and also academic-aptitude tests, which are essentially similar) predict less well at educational levels higher than the elementary grades, for at higher levels subject matter becomes more varied. Even at the elementary level, predictions of achievement have been poor in connection with the *initial* stages of learning to read, in spelling, and in the arts. The defender of the IQ test might say that intelligence is not involved in such subjects. But he would not only be wrong, he would also be dodging problems.

One Intelligence, or Many Abilities?

The father of IQ tests, Alfred Binet, believed firmly that intelligence is a very complex affair, comprising a number of different abilities, and he manifested this conviction by introducing tests of many kinds into his composite scale. He did not know what the component abilities are, although he suggested that there are several different kinds of memory, for example. He went along with the idea of using a single, overall score, since the immediate practical goal was to make a single administrative decision regarding each child.

Test-makers following Binet were mostly unconcerned about having a basic psychological theory for intelligence tests, another example of technology running far in advance of theory.

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There was some concern about theory in England, however, where Charles Spearman developed a procedure of factor analysis by which it became possible to discover component abilities (*1*). Spearman was obsessed with a very restricting conception that there is a universal *g* factor that is common to all tests that have any claim to the label of "intelligence tests," where each test has its own unique kind of items or problems. His research, and that of others in his country, found, however, that correlations between tests could not be fully accounted for on the basis of a single common factor (*2*). They had to admit the existence of a number of "group" factors in addition to *g*. For example, sets of tests having verbal, numerical, or spatial material, respectively, correlated higher within sets than with tests in other sets. The extra correlation among tests within sets was attributed to additional abilities each of limited scope.

Factor analyses in the United States have followed almost exclusively the multiple-factor theory of Thurstone (*3*), which is more general than Spearman's. In Thurstone's conception, a *g* factor is not necessary but analysis by his methods would be likely to find it if the intercorrelations warrant such a result. It is not necessary to know the mathematics basic to factor theory in order to follow the remaining content of this article, but for those who wish additional insights the next few paragraphs present the minimum essentials of a mathematical basis. To all readers it may be said that factor analysis is a sensitive procedure, which, when properly used, can answer the taxonomic questions of *what* intellectual abilities or functions exist and what their properties are.

The basic equation in multiple-factor theory, in matrix form, is $Z = FC$, where Z is a matrix of test scores, of order n by N, where N individuals have all taken n different tests. Z indicates that the scores are in standard form, that is, each element $z = (X - \overline{X})/s_x$, where X is a "raw" score on an arbitrary scale, $\overline{X}$ is the mean of the raw scores in the sample of N individuals, and s_x is the standard deviation. In the basic equation, F stands for the "complete factor matrix," which is of order n by $(r + n)$, where r is the number of *common* factors. The addition of n columns indicates that there are n *specific* factors or components, one for each test. In this matrix, f_{ij} is the loading or weight for test I in connection with factor J. C is of the order $(r + n)$ by N and represents the scores of N individuals on $(r + n)$ factors. The basic equation means that for each individual his standard score z_{ij} in a particular test is a weighted sum of his $(r + n)$ factor scores, each factor score also in standard form. An assumption for this form of the equation is that the factors are orthogonal (uncorrelated) variables.

The factor-analysis problem is to derive the matrix of common-factor loadings, A, given the score matrix for N individuals in n tests. The interest is in only the r common factors. The analysis ordinarily starts with intercorrelations among the n tests. The reduced (specifics ignored) intercorrelation matrix R is mathematically related to the factor matrix A by the equation $R = AA'$, where A represents only the common-factor components in F, and A' is the transpose of A. R can be computed from empirical data by the equation $R = ZZ'/N$. Starting with the computed correlation matrix R, the problem is to find the common-factor matrix A. Methods for accomplishing this operation are described by Harman (*4*).

Very rarely, indeed, does anyone using the multiple-factor approach find and report a *g* factor. The reason is that there are too many zero correlations among tests of intellectual qualities, where one genuine zero correlation would be sufficient to disallow a *g* factor that is supposed to be universal. My examination of more than 7000 intercorrelations, among tests in the intellectual category, showed at least 17 percent of them to be acceptable as zero correlations (*5*). The multiple factors usually found are each commonly restricted to only a few tests, where we may ignore factor loadings less than .30 as being insignificant, following common practice.

Discovery of Multiple Abilities

Only a few events in discovering factors by the Thurstone approach will be mentioned. In Thurstone's first major study (*6*) as many as nine common factors were thought to be sufficiently interpretable psychologically to justify calling them "primary mental abilities." A factor is interpreted intuitively in terms of the apparent human resource needed to do well in the set of tests loaded strongly together on the mathematical factor. A distinction between mathematical factors and psychological factors is important. Surface features of the tests in the set may differ, but examinees have to perform well in some unique way in all of them. For example, Thurstone designated some of the abilities as being visual-perceptual, inductive, deductive, numerical, spatial, and verbal. Two others dealt with rote memory and word fluency. Thurstone and his students followed his 1938 analysis with others that revealed a few additional kinds of abilities.

Another major source of identified intellectual abilities was the research of aviation psychologists in the U.S. Army Air Force during World War II (*7*). More important than the outcome of adding to the number of intellectual abilities that called for recognition was the fact that where Thurstone had found one spatial ability, there proved to be at least three, one of them being recognized as spatial orientation and another as spatial visualization. Where Thurstone had found an inductive ability, there were three reasoning abilities. Where Thurstone had found one memory ability, there were three, including visual memory. In some of these cases a Thurstone factor turned out to be a confounding of two or more separable abilities, separable when more representative tests for each factor were analyzed together and when allowance was made for a sufficient number of factors. In other cases, new varieties of tests were explored—new memory tests, space tests, and reasoning tests.

The third major event was in the form of a program of analyses conducted in the Aptitudes Research Project at the University of Southern California since 1949, in which attention was first concentrated on tests in the provisional categories of reasoning, creative thinking, planning, evaluation, and problem-solving (*8*). Nearly 20 years later, the number of separate intellectual abilities has increased to about 80, with at least 50 percent more predicted by a comprehensive, unified theory. The remainder of this article is mainly concerned with that theory.

The Structure-of-Intellect Model

Two previous attempts to put the known intellectual abilities into logical schema had been made by Burt (*9*) and Vernon (*10*), with similar results. In both cases the models were of hierarchical form, reminiscent of the Linnaeus taxonomic model for the animal kingdom. Following the British tradition of emphasis upon *g*, which was placed at the apex of the system, there were broad subdivisions under *g* and under each subdivision some sub-subcategories, on down to abilities that are regarded as being very narrow in scope.

My first attempts (*11*) found that the hierarchical type of model had to be discarded for several reasons. First, there had to be a rejection of *g* itself, for reasons mentioned earlier. Furthermore, most factors seemed to be of somewhat comparable level of generality, where generality is operationally defined in terms of the number and variety of tests found to represent each ability. There did appear to be categories of abilities, some concerned with discovery or recognition of information, memory for information, productive thinking, and evaluation, with a number of abilities in each category, but there are other ways of organizing categories of abilities. The most decisive observation was that there were a number of parallels between abilities, in terms of their common features.

Some examples of parallels in abilities will help. Two parallel abilities differ in only one respect. There was known to be an ability to see relations between perceived, visual figures, and a parallel ability to see relations between concepts. An example of a test item in the first case would be seeing that one figure is the lower-left half of another. An item in the second case might require seeing that the words "bird" and "fly" are related as object and its mode of locomotion. The ability to do the one kind of item is relatively independent of the ability to do the other, the only difference being that of kind of information—concrete or perceived in the one case and abstract or conceived in the other.

For a pair of abilities differing in another way, the kind of information is the same for both. One of the abilities pertains to *seeing* class ideas. Given the set of words *footstool, lamp, rocker, television,* can the examinee grasp the essence of the nature of the class, as shown by his naming the class, by putting another word or two into it, or by recognizing its name among four alternatives? The ability pertains to discovery or recognition of a class concept. In another kind of test we ask the examinee to *produce* classes by partitioning a list of words into mutually exclusive sets, each with a different class concept. These two abilities are relatively independent. The one involves a process of understanding and the other a process of production. These processes involve two psychologically different kinds of operation.

A third kind of parallel abilities has pairs that are alike in kind of information involved and in kind of operation. Suppose we give the examinee this kind of test item: "Name as many objects as you can that are both edible and white." Here we have given the specifications for a class and the examinee is to produce from his memory store some class members. The ability involved was at first called "ideational fluency." The more of appropriate members the examinee can produce in a limited time, the better his score. In a test for a parallel ability, instead of producing single words the examinee is to produce a list of sentences. To standardize his task for testing purposes and to further control his efforts, we can give him the initial letters of four words that he is to give in each of a variety of sentences, for example: W_____ c_____ s_____ d_____. Without using any word twice, the examinee might say, "Why can't Susan dance?," "Workers could seldom deviate," or "Weary cats sense destruction." The ability was first called "expressional fluency." The kind of information in both these tests is conceptual, and the kind of operation is production.

But the kind of operation in the last test is different from that for the classifying test mentioned before. In the classifying test, the words given to the examinee are so selected that they form a unique set of classes and he is so told. The operation is called "convergent production." In the last two tests under discussion, there are many possible responses and the examinee produces alternatives. The operation is called "divergent production." It involves a broad searching or scanning process. Both operations depend upon retrieval of information from the examinee's memory store.

The difference between the two abilities illustrated by the last two tests is in the nature of the things produced. In the first case they are single words that stand for single objects or concepts. The thing produced, the "product," is a *unit* of information. In the second case, the product is an organized sequence of words, each word standing for a concept or unit. This kind of product is given the name of "system."

In order to take care of all such parallels (and the number increased as time went on and experience grew), a matrix type of model seemed called for in the manner of Mendeleev's table of chemical elements. The differences in the three ways indicated—operation (kind of processing of information), content (kind of information), and product (formal aspect of information) —called for a three-dimensional model. Such a model has been called "morphological" (*12*). The model as finally completed and presented in 1959 (*13*) is illustrated in Fig. 1. It has five categories of operation, four categories of content, and six categories of product.

It is readily seen that the theory calls for 5 × 4 × 6, or 120, cubical cells in the model, each one representing a unique ability, unique by virtue of its peculiar conjunction of operation, content, and product. The reader has already been introduced to three kinds of operation: cognition (discovery, recognition, comprehension), divergent production, and convergent production. The memory operation involves putting information into the memory store and must be distinguished from the memory store itself. The latter underlies all the operations; all the abilities depend upon it. This is the best logical basis for believing that the abilities increase with experience, depending upon the kinds of experience. The evaluation operation deals with assessment of information, cognized or produced, determining its goodness with respect to adopted (logical) criteria, such as identity and consistency.

The distinction between figural and semantic (conceptual) contents was mentioned earlier. The distinguishing of symbolic information from these two came later. Symbolic information is presented in tests in the form of letters or numbers, ordinarily, but other signs that have only "token" value or meaning can be used.

The category of behavioral information was added on the basis of a hunch; no abilities involving it were known to have been demonstrated when it was included. The basis was E. L. Thorndike's suggestion (*14*) many years ago that there is a "social intelligence," distinct from what he called "concrete" and "abstract" intelligences. It was decided to distinguish "social intelligence" on the basis of kind of information, the kind that one person derives from observation of the behavior of another. Subsequent experience has demonstrated a full set of six behavioral-cognition abilities as predicted by the model, and a current analytical investigation is designed to test the part of the model that includes six behavioral-divergent-production abilities. In a test for cognition of behavioral systems, three parts of a four-part cartoon are given in each item, with four alternative parts that are potential completions. The examinee has to size up each situation, and the sequence of events, correctly in order to select the appropriate part. As a test for divergent production of behavioral systems, the examinee is given descriptions of three characters, for example, a jubilant man, an angry woman, and a sullen boy, for which he is to construct a number of alternative story plots involving the characters and their moods, all stories being different.

The reader has already encountered four kinds of products: units, classes, relations, and systems, with illustrations. The other two kinds of products are transformations and implications. Transformations include any kind of change: movement in space, rearrangement or regrouping of letters in words or factoring or simplifying an equation, redefining a concept or adapting an object or part of an object to a new use, revising one's interpretation of another person's action, or rearranging events in a story. In these examples the four kinds of content are involved, from figural to behavioral, illustrating the fact that all six kinds of products apply in every content category.

Implied information is suggested by other information. Foresight or prediction depends upon extrapolating from given information to some naturally following future condition or event. If I make this move in chess, my knight will be vulnerable. If I divide by X, I will have a simpler expression. If it rains tonight, my tent will leak. If I whistle at that girl, she will turn her head. The "If . . . then" expression well describes an instance of implication, the implication actually being the thing implied.

Some Consequences of the Theory

The most immediate consequence of the theory and its model has been its heuristic value in suggesting where to look for still undemonstrated abilities. The modus operandi of the Aptitudes Research Project from the beginning has been to hypothesize certain kinds of abilities, to create new types of tests that should emphasize each hypothesized ability, then factor analyze to determine whether the hypothesis is well supported. With hypotheses generated by the model, the rate of demonstration of new abilities has been much accelerated.

At the time this article was written, of 24 hypothesized abilities in the category of cognition, 23 had been demonstrated. Of 24 expected memory abilities, 14 were recognized. In the other operation categories of divergent production, convergent production, and evaluation, 16, 13, and 13 abilities, respectively, were accounted for, and in all these categories 17 other hypotheses are under investigation. These studies should bring the number of demonstrated abilities close to the century mark. It is expected that the total will go beyond the 120 indicated by the model, for some cells in the figural and symbolic columns already have more than one ability each. These proliferations arise from the differences in kind of sensory imput. Most known abilities are reperesented by tests with visual input. A few have been found in tests with auditory input, and possibly one involving kinesthetic information. Each one can also be placed in the model in terms of its three sources of specification—operation, content, and product.

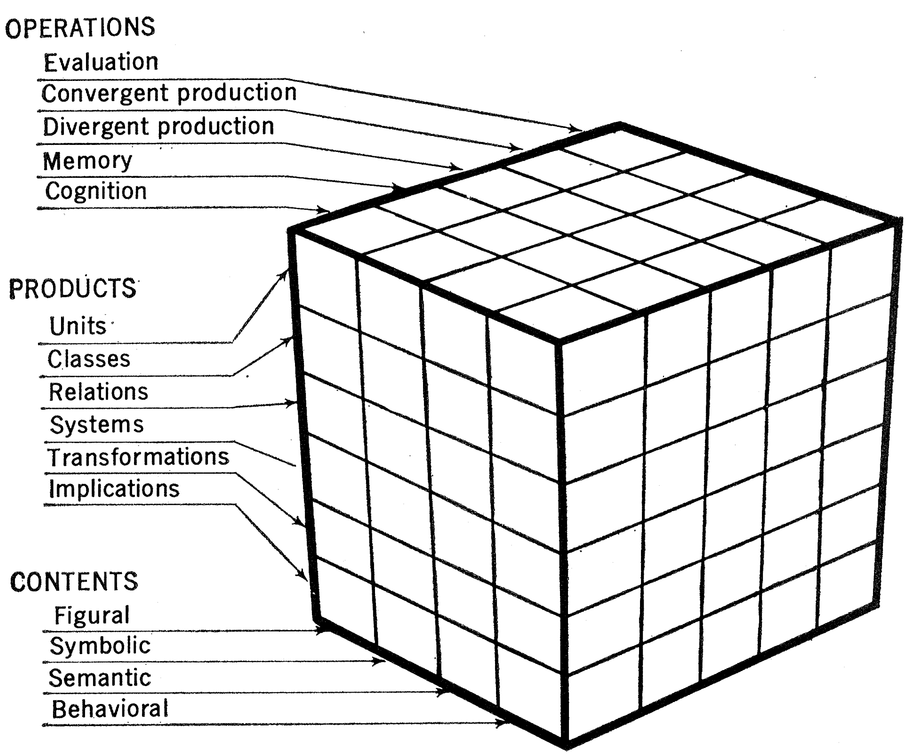

Fig. 1. The structure-of-intellect model.

Having developed a comprehensive and systematic theory of intelligence, we have found that not the least of its benefits is an entirely new point of view in psychology generally, a view that has been called "operational-informational." I have elaborated a great deal upon this view elsewhere (*15*). Information is defined for psychology as that which the organism discriminates. Without discrimination there is no information. This far, there is agreement with the conception of information as viewed by communication engineers, but beyond this point we part company. Psychological discriminations are most broadly and decisively along the lines of kinds of content and kinds of products, from which arise hiatuses between intellectual abilities. Further discriminations occur, of course, within the sphere of a single ability. I have proposed that the 4 × 6 intersections of the informational categories of the SI (structure of intellect) model provide a psychoepistemology, with 24 subcategories of basic information. I have also proposed that the six product categories—units, classes, relations, systems, transformations, and implications—provide the basis for a psycho-logic (*16*). Although most of these terms are also concepts in modern logic, a more complete representation appears in mathematics.

The operational-informational view regards the organism as a processor of information, for which the modern, high-speed computer is a good analogy. From this point of view, computersimulation studies make sense. In addition to trying to find out how the human mind works by having computers accomplish the same end results, however, it might be useful, also, to determine how the human mind accomplishes its ends, then to design the computer that performs the same operations. Although a psychology based upon the SI concepts is much more complicated than the stimulus-response model that became traditional, it is still parsimonious. It certainly has the chance of becoming more adequate. The structure of intellect, as such, is a taxonomic model; it provides fruitful concepts. For theory that accounts for behavior, we need operational models, and they can be based on SI concepts. For example, I have produced such a model for problem-solving (*17*).

There is no one problem-solving ability. Many different SI abilities may be drawn upon in solving a problem, depending upon the nature of the problem. Almost always there are cognitive operations (in understanding the nature of the problem), productive operations (in generating steps toward solution), and evaluative operations (in checking upon both understanding and production). Memory operations enter in, to keep a record of information regarding previous steps, and the memory store underlies all.

There is something novel about producing solutions to problems, hence creative thinking is involved. Creative thinking depends most clearly upon divergent-production operations on the one hand, and on transformations on the other. Thus, these two categories have unique roles in creative problem-solving. There is accordingly no one unique ability to account for creative potential. Creative production depends upon the area in which one works, whether it is in pictorial art, music, drama, mathematics, science, writing, or management. In view of the relative independence of the intellectual abilities, unevenness of status in the various abilities within the same person should be the rule rather than the exception. Some individuals can excel in more than one art form, but few excel in all, as witness the practice of having multiple creative contributors to a single motion picture.

The implications of all this for education are numerous. The doctrine that intelligence is a unitary something that is established for each person by heredity and that stays fixed through life should be summarily banished. There is abundant proof that greater intelligence is associated with increased education. One of education's major objectives should be to increase the stature of its recipients in intelligence, which should now mean stature in the various intellectual abilities. Knowing what those abilities are, we not only have more precise goals but also much better conceptions of how to achieve those goals.

For much too long, many educators have assumed, at least implicitly, that if we provide individuals with information they will also be able to use that information productively. Building up the memory store is a necessary condition for productive thinking, but it is not a sufficient condition, for productive abilities are relatively independent of cognitive abilities. There are some revealing findings on this point (*18*). In a sample of about 200 ninth-grade students, IQ measurements were available and also the scores on a large number of tests of various divergent-production (DP) abilities. Table 1 shows a scatter diagram with plots of DP scores (*19*) as a function of IQ. The striking feature of this diagram pertains to the large proportion of high-IQ students who had low, even some very low, DP scores. In general, IQ appears to set a kind of upper limit upon DP performance but not a lower limit. The same kind of result was true for most other DP tests.

Table 1. Scatterplot of Expressional Fluency (one aspect of divergent production) scores in relation to CTMM (California Test of Mental Maturity) IQ.

DP score	Intelligence quotient								
	60–69	70–79	80–89	90–99	100–109	110–119	120–129	130–139	140–149
50–59						1	3		1
40–49						2	4	1	
30–39			2	3	4	11	17	6	2
20–29			1	3	10	23	13	7	
10–19	1	5	3	9	11	19	7	3	1
0– 9	1	3	1	4	10	11	2		

On the basis of present information, it would be best to regard each intellectual ability of a person as a somewhat generalized skill that has developed through the circumstances of experience, within a certain culture, and that can be further developed by means of the right kind of exercise. There may be limits to abilities set by heredity, but it is probably safe to say that very rarely does an individual really test such limits. There is much experimental evidence, rough though it may be, that exercise devoted to certain skills involved in creative thinking is followed by increased capability (*15*, p. 336). Although special exercises have their demonstrated value, it is probably better to have such exercises worked into teaching, whatever the subject, where there are opportunities. Informing individuals regarding the nature of their own intellectual resources, and how they enter into mental work, has also been found beneficial.

There is not space to mention many other problems related to intelligence—its growth and its decline, its relation to brain anatomy and brain functions, and its role in learning. All these problems take on new aspects, when viewed in terms of the proposed frame of reference. For too long, many investigators have been handicapped by using a single, highly ambiguous score to represent what is very complex but very comprehensible.

Without the multivariate approach of factor analysis, it is doubtful whether any comprehensive and detailed theory of the human intellect, such as the model in Fig. 1, could have been achieved. Application of the method uncovers the building blocks, which are well obscured in the ongoing activities of daily life. Although much has already been done by other methods to show the relevance and fruitfulness of the concepts generated by the theory (*15*), there is still a great amount of developmental work to be done to implement their full exploitation, particularly in education.

Summary

In this limited space I have attempted to convey information regarding progress in discovering the nature of human intelligence. By intensive factor-analytic investigation, mostly within the past 20 years, the multifactor picture of intelligence has grown far beyond the expectations of those who have been most concerned. A comprehensive, systematic theoretical model known as the "structure of intellect" has been devel-

oped to put rationality into the picture.

The model is a cubical affair, its three dimensions representing ways in which the abilities differ from one another. Represented are: five basic kinds of operation, four substantive kinds of information or "contents," and six formal kinds of information or "products," respectively. Each intellectual ability involves a unique conjunction of one kind of operation, one kind of content, and one kind of product, all abilities being relatively independent in a population, but with common joint involvement in intellectual activity.

This taxonomic model has led to the discovery of many abilities not suspected before. Although the number of abilities is large, the 15 category constructs provide much parsimony. They also provide a systematic basis for viewing mental operations in general, thus suggesting new general psychological theory.

The implications for future intelligence testing and for education are numerous. Assessment of intellectual qualities should go much beyond present standard intelligence tests, which seriously neglect important abilities that contribute to problem-solving and creative performance in general. Educational philosophy, curriculum-building, teaching procedures, and examination methods should all be improved by giving attention to the structure of intellect as the basic frame of reference. There is much basis for expecting that various intellectual abilities can be improved in individuals, and the procedures needed for doing this should be clear.

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Education for Management and Technology in the 1970's

The universities and business must foster entrepreneurship and its interaction with technology.

Howard W. Johnson

Any time in human history is one, I suppose, of paradox—of contradiction, of extreme and opposite conditions side by side. Wealth and poverty, beauty and squalor, genius and ignorance—the human condition tolerates, seems even to foster their coexistence. Dickens captured the mood of an earlier era when he wrote in *A Tale of Two Cities:*

> It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair.

But perhaps more than ever before in our lifetimes, such extremes exist now: the paradox of hope and despair, the contrast of the potential and the reality —extremes of which technology at times seems the common cause. For technology is at once our blessing and our bane, the wellspring of our aspirations, yet the threat to our well-being. Technology is both social benefactor and social calamity. It offers us nuclear power and the specter of thermonuclear destruction, personal transportation and urban pollution, computers which multiply our creative power and threaten our privacy, mass communication and mass propaganda, an affluent but alienated youth. Technology offers the potential of the good life, but seems unable to lessen the poverty around us. A magnificent Lincoln Center exists side by side with the slums of Harlem. There are rich nations and poor nations, and the gulf steadily widens. Huxley may well have been right to ask: "What are you going to do with all these new things?"

Clearly science is not enough. But there is no turning back. The hope, I believe, lies in a partnership of technology and management (both industrial and social), intensely responsive to human need, to so order the distribution of technology's products and our national priorities as to resolve the paradox.

Remarkably, only concerning the advantage of effective management is there reasonable agreement for the moment. Management is regarded as a positive virtue from all points of view: American, British, Russian—perhaps even Chinese. The focus is thus strongly on the improvement of management—on education for management—and especially on the symbiotic relationship existing between management and technology. Societies will be strong economically in proportion to the strength of their management systems, their ability to harness technology in the service of the market, a term that here includes both the individual's and society's needs

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