

On Evaluating Scientific Research: The Contribution of the Psychology of Science

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ABSTRACT

This paper critically discusses the nature of various schemes for evaluating scientific research. Through the use of Jungian personality theory, it attempts to explicate the psychological forces and assumptions underlying the vast majority of evaluation schemes. The paper argues that most schemes are greatly restricted in their choice of an underlying psychological basis. It is argued that science administration, evaluation, and technological forecasting all require a greater ability to appreciate, and even more important to integrate, the psychological functions described in this paper.

"It has been lately fashionable in some quarters to think that physical science normally progresses by moving on the whole fairly calmly in one direction, and that such progress is interrupted only at certain periods of great upheaval in science.

"But this can be true only in a limited sense. Not far below the surface, there have coexisted in science, in almost every period since Thales and Pythagoras, sets of two or more antithetical systems or attitudes, for example, one reductionistic and the other holistic . . .

"Science has always been propelled and buffeted by such contrary or antithetical forces. Like vessels with draught deep enough to catch more than merely the surface current, scientists of genius are those who are doomed, or privileged, to experience these deeper currents in their complexity. It is precisely their special sensitivity to contraries that has made it possible for them to do so, and it is an inner necessity that has made them demand nothing less for themselves [5, pp. 375-376]."

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Introduction

In previous papers [16, 18, 19, 20] one or more aspects of the problem of selecting and evaluating scientific research has been addressed. This paper treats the problem of selecting and evaluating scientific research from an alternate and more encompassing point of view. It suggests a framework for evaluating evaluation frameworks. It suggests a perspective or framework whereby the psychological attitudes which underlie various modes of evaluation may be identified and thereby themselves be evaluated.

The framework to be presented in this paper makes clear why there are currently no evaluation frameworks which have attempted to combine these various attitudes into a coordinated whole. The difficulty is one of reconciling and of integrating radically distinct, and often hostile, psychological viewpoints.

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JUNGIAN PERSONALITY THEORY

The personality typology that is used in this paper is that of C. G. Jung [9, 10]. The Jungian typology is used for two major reasons: (1) the typology can be directly related to different styles of doing science (see the Appendix); and hence, it allows us to compare these styles in an interesting manner; (2) the Jungian typology does not prescribe one of the four major personality types as superior or inherently better than any of the others but instead points out that each type has its major strengths as well as weaknesses [8, 11, 15, 17, 21].

For the purposes of this paper, two particular dimensions of the Jungian typology are of special importance. The first dimension corresponds to the kind of "input-data" an individual characteristically prefers to take in from the outside world. The second dimension corresponds to an individual's preference for the kind of "decision-making process" that he characteristically brings to bear upon his preferred kind of input-data.

According to Jung, individuals can take in data from the outside world by either *sensation* or *intuition* but not by both simultaneously. As a result, individuals tend to develop a preference for one mode of input or the other. Sensation refers to those individuals who typically take in information via the senses, who are most comfortable when attending to the details of any situation, and who prefer concrete, specific facts. In contrast, intuition refers to those individuals who typically take in information by means of their imagination, by seeing the whole—the gestalt—of any situation. These individuals typically prefer the hypothetical possibilities in any situation to the "actual" facts. It should be stressed that all individuals perceive with both of these functions at different times. But as Jung argues, individuals tend to develop a preferred way of perceiving, and in fact, cannot apply both types of perception or data-input at the same exact time.

According to Jung, there are two basic ways of reaching a decision: *thinking* and *feeling*. Thinking is the process of reaching a decision that is based on impersonal, analytical modes of reasoning. Feeling on the other hand is the process of a reaching of a decision that is based on personalistic, value judgments that may be highly unique to the particular individual. Thus, however one takes in data (either by intuition or sensation) an individual may come to some conclusion about the data either by a logical, impersonal analysis (thinking) or by a subjective, personal process (feeling).

Combining the two data input modes (sensation and intuition) with the two decision making modes (feeling and thinking) in all possible ways results in the following four Jungian Personality types:

- (1) sensation-thinking (ST),
- (2) sensation-feeling (SF),
- (3) intuition-thinking (NT), and
- (4) intuition-feeling (NF).¹

Results from a previous study [17] are helpful in giving a concrete feeling for the meaning of each of these types as well as for their implications. Over one hundred middle to high level managers were asked to describe their image of their ideal organization. The managers were purposefully asked to write about their concept of their *ideal*, as opposed

¹ The symbol N is used to signify intuition since it is customary in Jungian personality theory to reserve the symbol I for the function introversion [23]. We shall adhere to this customary notation even though there is no possibility of confusion since for reasons of convenience we have not treated the additional Jungian dimension, introversion (I)–extroversion (E).

to their *real*, organization in order to bring out their personality differences. That is, the notion of an "ideal organization" is sufficiently open-ended that it serves as a projective device for bringing out personality differences. A content analysis of the descriptions indicates that:

(1) there is a remarkable and very strong *similarity* between the descriptions of those individuals who have the same personality type² (e.g., ST);

(2) there is a remarkable and very strong *difference* between the descriptions of the four personality types. That is, individuals of the same personality types tend to have the same image of an ideal organization whereas different personality types tend to have very different images. In a word, the ideal of one type is distinctly not that of another. As a consequence, the results are helpful in answering the question of which kind of organization best appeals to which kind of personality. In other words, the results have important implications for the field of organizational behavior and the design of large-scale organizations [7, 8].

The descriptions of ST individuals are characterized by an extreme emphasis and concentration on specifics, on factual details. ST types are extremely sensitive to the physical features of their work environment. For example, the descriptions of ST types display an extreme preoccupation with environments that are neither "to hot" or "to cold" but "just right". The ideal organization of ST's is one that is characterized by complete control, certainty, and specificity. In their ideal organization, everybody knows exactly what his or her job is. There is no uncertainty as to what is expected in all circumstances. Further, ST organizations are impersonal. The emphasis is on work, and work roles, not on the particular individuals who fill the roles. It thus comes as no surprise that the ideal organization of ST's is authoritarian and bureaucratic. There is a single leader at the top and a well-defined hierarchical line of authority that extends from the very top down to all of the lower rungs of the organization. In an ST organization, the individuals exist to serve the goals of the organization, not the organization to serve the goals of the individuals. Finally, the goals of an ST organization are realistic, down-to-earth, limited, and more often than not, narrowly economic.

The descriptions of NT's are marked by an extreme emphasis on broad, global issues. In describing their ideal organization, NT's show an almost complete disdain for specific, detailed facts. NT's neither specify the detailed work rules, roles, nor lines of authority but instead focus on general concepts and issues. To put it somewhat differently, if the organizational goals of ST's are concerned with well-defined, precise *micro* economic issues, then the goals of NT's are concerned with fuzzy, ill-defined, *macro* economic issues like "an equitable wage for all workers". NT organizations are also impersonal like ST organizations. However, where ST's focus on the details of a specific impersonal organization, NT's focus on impersonal concepts and theories of organization. For example, they are concerned with concepts of efficiency in the abstract. Likewise, whereas in an ST organization individuals exist to serve the particular organization, in an NT organization individuals exist to serve the intellectual and theoretical concept of the organization in general. In a word, if ST organizations are impersonally realistic, then NT organizations are impersonally conceptual.

² As measured by the Myers-Briggs [23] personality instrument which is an operationalization of the Jungian typology.

The descriptions of NF's are also marked by an extreme preoccupation with broad, global themes and issues. NF's also show an extreme distain towards getting down to specifics. NF's are similar to NT's in that both take a broad view of organizations. However NF's differ from NT's in that where the emphasis of NT's is on the general *theory* or *theoretical* aspects of organizations, the emphasis of NF's is on the most general *personal* and *human* goals of organizations. Thus, NF organizations are concerned with "serving humanity", e.g., "with making a contribution to mankind". NF's differ from both ST's and NT's in that for both ST's and NT's the individual exists to serve the organization where for NF's the organization exists to serve the personal and social needs of people. Since in Jungian personality theory the NF type is the extreme opposite of the ST type (as the SF type is the extreme opposite of the NT), it is not surprising to find that the ideal organization of NF's is the exact opposite of ST's. Thus, if an ST organization is authoritarian and bureaucratic with well-defined rules of behavior, then an NF organization is completely decentralized with no clear lines of authority, with no central leader, and with no fixed, prescribed rules of behavior. The descriptions of NF's incessantly talk about "flexibility" and "decentralization". As a matter of fact, many of the descriptions of NF's contain diagrams of their ideal organization which show them to be circular or wheel-like in structure rather than hierarchical. NF organizations are also idealistic as opposed to realistic. In essence, NF organizations are the epitome of organic, adaptive institutions [7].

If the ideal organizations of ST's and NF's are extreme opposites then the organizations of NT's and SF's are also extreme opposites. If NT's are concerned with the general theory of all organizations but not with the details of any particular organization, then SF's don't care about theory at all or issues in general. SF's are instead concerned with the detailed human relations in their particular organization. SF's are like ST's in that both are concerned with details and facts. However, SF's differ from ST's in that whereas the latter are concerned with detailed *work rules* and *roles*, the former are concerned with the *human qualities of the specific people* who fill the roles. SF's are in this sense similar to NF's. SF's differ from NF's in the sense that where NF's are concerned with people in general, SF's are concerned with individuals in particular. SF organizations are also realistic as opposed to idealistic. Like ST's, SF's are also concerned with the detailed work environment although where for ST's the environment of concern is physical, for SF's it is the interpersonal environment that is of concern.

It should be clear by now that we are dealing with very different and distinct types of individuals.³ Each type is not only extremely different from each of the others, but even more to the point, each of the types has extreme difficulty in understanding and

³ By the notion of different "types," we do not mean to imply there are literally "four basic kinds of people and that each person is one of these and one only." Rather, we merely mean to imply that these four types help us to come to grips with the elusive problem of handling different styles of behaving. As Jung himself put it:

Do not think I am putting people into this box or that and saying, "He is an intuitive", or "He is a thinking type". People often ask me, "Now, is So-and-So not a thinking type?" I say, "I never thought about it", and I did not. It is no use at all putting people into drawers with different labels. But when you have a large empirical material, you need critical principles of order to help you to classify it. I hope I do not exaggerate, but to me it is very important to be able to create a kind of order in my empirical material, particularly when people are troubled and confused or when you have to explain them to somebody else. For instance, if you have to explain a wife to a husband or a husband to a wife, it is often very helpful to have these objective criteria, otherwise the whole thing remains "He said"—She said" [9, p. 19].

appreciating one another. In fact, the more that any two types differ from one another, the more difficulty they experience in appreciating one another. Thus, NF's and ST's find it more difficult to get along with one another than they do with either of the two remaining types (NT's and SF's). The basic reason is that NF's and ST's share absolutely nothing in common; i.e., they have no personality function in common. By the same token, SF's and NT's experience the most difficulty in getting along with one another. In Jungian terms, NF's and ST's, and NT's and SF's, are the respective "shadow sides" of one another. That is, the strength of one type (e.g., ST) is the weakness of the other (NF). Another way to put this is to say that what one type has developed in great depth is largely lacking or undeveloped in its exact opposite. Thus, for example, if the strength of ST's lies in their attention to detail and the gathering of facts (S) coupled with their passion for impersonal analysis (T), then they are weakest at sizing up and sensing the intuitive possibilities (N) in any situation and in making a personal value judgment or decision (F) with regard to the situation. The contention of this paper is that what holds true for individual personality types, i.e., their glaring strengths as well as their glaring weaknesses, also holds true for the majority of evaluation schemes (see Table 1).

A JUNGIAN ANALYSIS OF EVALUATION

It is rare to find an evaluation structure that is pure as each of the preceding types. Most structures are mixtures and amalgamations of each of the four Jungian types. This does not mean however that in the majority of structures one type does not predominate. As a matter of fact, in most structures one type does predominate. Further, as we shall be at great pains to observe later, a framework that is based on amalgamation is not the same as one that integrates each of these types in a deep and meaningful psychological sense.

It would take far more space than is available here to establish the case that the psychological function that predominates in the overwhelming majority of evaluation schemes is that of ST. This does not mean that the other functions are entirely absent but that they are ultimately under the control and domination of ST. To a large extent this is but a reflection of the fact that the dominant psychological attitude underlying modern science is that of ST. To be sure NT plays a strong, but nonetheless *secondary*, supporting role [13, 15].⁴

Table 1 shows four different evaluation procedures, mechanisms, concerns, and criteria that arise from a consideration of each of the four Jungian types. That is, Table 1 shows the particular form that each of the four Jungian types assumes when translated into an evaluation scheme. A detailed examination of each of these four schemes would take us too far afield. However, given the fact that ST plays such a predominant role in modern science and that NF is the psychological attitude which is the most removed from ST, it behooves us to compare at least these two particular attitudes.

⁴ Jung writes:

Science is under all circumstances an affair of the intellect, and the other psychological functions are subordinated to it as objects. The intellect is the sovereign of the scientific realm . . . Science as an end in itself is assuredly a high ideal, yet its consistent fulfillment brings about as many "ends in themselves" as there are sciences and arts. Naturally this leads to a high differentiation and specialization of the particular functions concerned, but also to their detachment from the world and from life as well as to a multiplication of specialized fields which gradually lose all connection with one another. The result is an impoverishment and dessication not merely in the specialized fields but also in the psyche of every man who has differentiated himself up or sunk down to the specialist level [10, pp. 57-58].

TABLE 1
A Comparison of Different Jungian-Based Evaluation Schemes

Psychological Type	ST	NT
Characteristics	reductionistic (discipline-oriented), impersonal, specific, analytical, technique-oriented, data-oriented, concerned with well-structured problems [16], short-time horizon, value-free approach	holistic [16] (interdisciplinary), impersonal, non-specific synthetic, problem-oriented, speculative-possibilities, concerned with interesting [3] theoretical problems, extended time-horizon, value-free approach to problems
Outcomes	verification and/or testing of existing theories and/or data, concrete additions to existing scientific knowledge (Normal science [14, 15])	discovery and invention of novel theories and hypotheses, implications for the opening up of new areas of research (Revolutionary science [14, 15])
Criteria	clear statement of detailed research hypotheses, aims and objectives of research; logical design of research study; high emphasis on experimental control, rigor, precision	broad statement of the aims and objectives of the research; evidence of the openness and flexibility of both the researcher and the research; imagination, theoretical soundness, speculative
Procedures	explicit scoring of research payoffs, relative ranking of proposed research against competitors [26]	explicit scoring of research payoffs, relative rankings of proposed research against competitors [26]
Psychological Type	SF	NF
Characteristics	reductionistic (discipline-oriented), personal, specific, analytical, technique-oriented, data-oriented, concerned with well-structured problems, short-time horizon, value-laden approach	holistic (interdisciplinary), personal, non-specific synthetic, problem-oriented, speculative-possibilities, concerned with ill-structured problems [16], indefinite time-horizon, value-laden approach to problems
Outcomes	collection of data, concrete additions to existing scientific knowledge (Normal science [14, 15])	discovery and invention of novel theories and hypotheses, implications for the opening up of new areas of research (Revolutionary science [14, 15])
Criteria	clear statement of detailed research hypotheses, aims and objectives of research; detailed outline and specification, data collection procedures, control	broad statement of the aims and objectives of the research; evidence of the openness and flexibility of both the researcher and the research; imagination, interesting [3], speculative, excitement, enthusiasm
Procedures	personal defense or research on concrete, subjective grounds, judicial review [26]	personal defense of research on intuitive, subjective grounds, judicial review [26]

The emphasis of ST approaches is on impersonal criteria, specificity, control, precision, rigor and an attitude of reductionism.⁵ The research is judged on its own merits according to the impersonal canons of research design and the significance of the research hypotheses themselves. The research is not judged, or at least it is not supposed to be, on the personal merits of the investigator. Personal criteria are supposed to be irrelevant. The emphasis in other words is on the hypotheses that will be tested as well as on the means that have been proposed for their testing. The ideal model for evaluation according to this attitude is the controlled experiment.⁶ The research is judged strictly on the ability of the researcher to lay out in a clear and unambiguous manner exactly what he proposes to do before he does it. Is the experimental design coherent and logical? Is the research broken down into a series of detailed steps that relate to one another in a logical and clear fashion? Are the research aims realizable in a finite period of time? Can progress be clearly and objectively demonstrated?

NF represents the complete opposite to this way of thinking. NF emphasizes that research, particularly creative research, can be not broken down into a series of neat, clean, precise steps that can be programmed beforehand. It emphasizes that in reality research is a highly personal affair, that it is permeated and guided by deep intuitive and

subjective thought processes. As far as we are aware of, the Nobelist Albert Szent-Gyorgyi is the best spokesman for this point of view. In a recent letter to *Science*, Szent-Gyorgyi starts by noting that scientists may be divided into two main types—the Apollonian and the Dionysian. The Apollonian comes closest to what we have called the ST type whereas the Dionysian most closely approximates the NF type. With great feeling and insight, Szent-Gyorgyi describes the differences between these two types of scientists and their implications for the growth of science:

The future of mankind depends on the progress of science and the progress of science depends on the support it can find. Science mostly takes the form of grants, and the present methods . . . unduly favor the Apollonian . . . The Apollonian clearly sees the future lines of his research and has no difficulty writing a clear project. Not so the Dionysian, who knows only the direction in which he wants to go out into the unknown; he has no idea what he is going to find there and how he is going to find it. Defining the unknown or writing down the subconscious is a contradiction in absurdum. In his work, the Dionysian relies to a great extent on accidental observation . . .

Being myself Dionysian, writing projects was always an agony for me . . . I always tried to live up to Leo Szilard's commandment, "don't lie if you don't have to." I had to. I filled up pages with words and plans I knew I would not follow. When I go home from my laboratory in the late afternoon, I often do not know what I am going to do the next day. I expect to think that up during the night. How could I tell them then, what I would do a year hence? [25, p. 966].

Towards an Integrated Evaluation Process

The argument of this paper has not been that ST approaches to evaluation are all wrong and should therefore be eliminated all together. Rather the argument has been that

⁵ The following illustrates well the attitudes of reductionism and specificity, not to mention the emphasis on criteria:

After the decision has been made to evaluate a certain group of R&D activities the next part of the evaluation framework is to divide the R&D activities selected into a set of subcategories. A two-tiered partition is recommended: division into fields, ranging in number between 5 and 12; and then, within each field, into a number of subfields. A Subject Matter Study Group would be formed for each field of R&D activities selected.

The main reason for disaggregating the collection of R&D activities into fields and subfields is organizational: to permit a relatively well-defined assignment of subtasks for making recommendations for change. With an array of subunits of activities, it is easier to be specific about what changes should be made in what activities than if there is no such substantive identity. Another reason for partitioning is that the method of evaluation that will be proposed involves in part subjectively comparing different sets of R&D activities according to prespecified criteria. Without a specific definition of what activities are in what set, these subjective comparisons would be impossible to make [26, p. 31].

⁶ We quote from a typical source:

Hardly any more persuasive proponent of the controlled experiment model can be found than Houston [6] whose paper argues very strongly for the appropriateness and singular power of controlled experiments as the model for evaluation studies. In broad outline, the essential feature of a controlled experiment is the active intervention of an experimenter who administers a treatment (program or project) to randomly selected subjects arranged in groups that are equivalent in the way in which they were chosen, there being at least one group to whom the treatment is administered and at least one group from whom the treatment in question is withheld or to whom an alternative treatment is given. The method of assuring equality between groups is through requiring that persons would have an equal (or at least known) chance of being placed in either the experimental group (treated) or the control (untreated) group. Measurement made on experimental and control groups allow comparisons to be made from which estimates can be made of the impact effectiveness of the treatment used [24, pp. 29–30].

each of the various approaches to evaluation picks up only a part at best of the many concerns and varied aspects of evaluation. If anything the argument has been that a total and comprehensive approach to evaluation should seek to incorporate all four of the approaches outlined in this paper. This requires that the attempt should be made to evaluate a project from all four of these viewpoints simultaneously. At the very least there should be a debate between the proponents of these various approaches to evaluation. As Wirt has so aptly put it:

The . . . element of strategy [for evaluation] concerns a way of coping with the special nature of R&D activity. The *proposed strategy is to adopt a judicial type of process rather than an analytical process as the basic means of conducting an R&D evaluation* [emphasis added]. The assumption is that the judicial process is more effective for analyzing the kind of evidence that can be developed about R&D programs than the scientific/analytical process (as typified by the experimental research/cost-benefit methodology). These two processes are distinctly different in the extent to which formal, analytical models are used in generating conclusions from data. In the scientific/analytical process, formal models are constructed and play a central role in analysis. In the judicial process, the results from formal models are used only as inputs, and subjective judgment plays the central role in analysis [26, p. 13].

From several applications of the Jungian framework to organizational problem solving [17], we can suggest a judicial process to move towards an integrated evaluation process, i.e., to foster the integration of the ST, NT, SF and NF evaluation characteristics, outcomes, criteria, and procedures. In particular, we have developed a setting for scientists (or research evaluators) to critically examine their underlying values, assumptions, problem perspectives, etc., in a manner that encourages the open confrontation of their differences and provides an atmosphere that is conducive to an integrated research evaluation. This model can conceivably be institutionalized as a general evaluation process as a matter of scientific policy.

Specifically, the first step in the judicial process is to bring together all the scientists concerned with some project or problem, or their representatives (e.g., if there is a large number of relevant scientists from different R&D departments). Each scientist or evaluator is asked to write out his view of the problem, what he sees as the objectives, the issues, the values, etc. Alternatively, we ask each scientist to write a story describing how the problem, project or issue arose, how he defines the nature of the problem, what scientific procedures should be used to address the problem, and how the problem would be *ideally* resolved.

The second step requires the scientists to form into Jungian groups (i.e., an ST, NT, SF, and NF group) either by their assessed Jungian psychological type [23] or by a content analysis of their problem descriptions and stories [17]. The scientists are asked to develop a group statement by combining or integrating their individual statements or stories. When the group statements have been prepared, each group shares with the others their view of the problem, etc., as indicated by their group discussions. This typically results in four very different perspectives, where the differences may be more extreme than the initial individual statements.

The third step in the judicial process, and perhaps the most central, explicitly examines the four differentiated group products and attempts to *integrate* them in some new form or synthesis. The process involves having two or more scientists from each of the four Jungian groups meet as an *integrated group*. This group then is asked to discuss their different perspectives, their assumptions, values, stories, etc. In essence, a "lively" debate develops in which the different perspectives are exaggerated, challenged, examined, denied, projected, etc. The need to evoke a debate among the four Jungian

approaches to evaluation is supported in several contexts [1, 2, 13, 15, 17, 20]. During this debate, as much as possible, each scientist is encouraged and pushed to critically question and address the strengths as well as the weaknesses of his own perspective. Once each scientist in the integrated group has achieved this objective, the process moves toward the synthesis stage. The atmosphere changes, and each member of the group attempts to provide integrative solutions, capitalizing on the strengths of each position while hopefully minimizing or subduing the weaknesses. Finally, this group *proposes* some integrated solution (evaluation) which satisfactorily (via consensus) addresses the issues developed by the different perspectives.

While it is beyond the scope of this paper to undertake a detailed comparison of the above psychologically-based evaluation procedure with the epistemic procedures outlined in a previous paper [20], a few remarks are nonetheless in order. In its pure form, the function of sensation most nearly corresponds to the Lockean Inquiring System while the function of thinking most nearly corresponds to the Leibnizian Inquiring System. The Kantian Inquiring System, on the other hand, best corresponds to the combined psychological functions of NT whereas the Hegelian Inquiring System cuts across the functions NT and NF in a complicated way (it also involves elements of the other positions as well, i.e., ST, and SF). In terms of the whole Jungian framework, the Singerian-Churchmanian Inquiring System best corresponds to what we have referred to as the integrated group or perspective. In effect, the Singerian-Churchmanian Inquirer is a meta-system and as such attempts to make maximal use of each of the previous systems as subordinate visions of reality. For a complimentary expression of this notion, see the excellent paper by Maruyama [12].

Concluding Remarks

In the end the biggest challenge is to science itself. The challenge is not only to learn how to do science from each of these perspectives (separately and combined), but also, how to train future scientists to appreciate each of these various psychological frames of mind. As Abraham Maslow put it:

It seems . . . that these "good," "nice" scientific words—prediction, control, rigor, certainty, exactness, preciseness, neatness, orderliness, lawfulness, quantification, proof, explanation, validation, reliability, rationality, organization, etc.—are all capable of being pathologized when pushed to the extreme. [13, p. 30].

All of these same . . . goals are also found in the growth-motivated scientist. The difference is that they are not neuroticized. They are not compulsive, rigid, and uncontrollable . . . They are not desperately needed, nor are they exclusively needed. It is possible for healthy scientists to enjoy not only the beauties of precision but also the pleasures of sloppiness, casualness, and ambiguity . . . They are not afraid of hunches, intuitions, or improbable ideas [13, p. 31].

Finally, the arguments of this paper indicate why science administration [2] and technological forecasting are such difficult activities [16, 19, 20]. For example, technological forecasting can never be a purely exact (i.e., ST) activity given the fact that forecasting not only involves our predicting the uncertain, the future, but even more fundamental, it involves our conceptualization of what we think the future will be like [20]. In this sense, technological forecasting demands a strong element of intuition. Both activities, that of science administration and technological forecasting, require individuals who can appreciate as well as reconcile diverse and antagonistic ways of conceptualizing problems [19]. Little wonder why we have had so few good examples of each.

Appendix

The following are examples of some of the forms that S, T, N and F assume respectively in science. For full details of the use of these forms (or portraits) for the measurement of the scientific personality type of a group of scientists, see *The Subjective Side of Science: An Inquiry into the Psychology of the Apollo Moon Scientists* [15].

INSTRUCTIONS

Below you will find four descriptions of *four* very different kinds of scientists. I would like you to read each description carefully, and then only after you have read each description, indicate the degree to which each description represents you.

Type A: The Hard Experimentalist

Type A is the kind of scientist who first and foremost regards himself as a *Hard Experimentalist*. He takes extreme pride in his carefully designed and detailed experimental work. In general, he prefers hard data gathering to abstract theorizing, intuitive synthesizing, or humanistic concerns. He feels that one really doesn't understand something until he has collected some hard data on it. He feels that abstract theorists have a tendency to get lost in their abstractions for their own sake and hence to mistake them for reality, that intuitive synthesizers have a tendency to engage in unwarranted extrapolation beyond the data at hand and that humanistic scientists have a tendency to become prone to gushy moralizing. His attitudes toward theorizing and speculating are modest. He feels that theorizing and speculating are only warranted when the data are available that clearly support such activities. He is quick to master complicated and sophisticated experimental techniques. He prefers to work on manageable, well-defined problems for which there are available standard, well-developed experimental methods of investigation. He tends to be technique-oriented rather than problem-oriented. In sum his approach to science is best described as Empirical-Inductive rather than Theoretical-Deductive.

Type B: The Abstract Theorizer

Type B is the kind of scientist who first and foremost regards himself as an *Abstract Theorizer*. He takes extreme pride in his ability to construct formal, analytical models of complicated physical phenomena. In general, he prefers building abstract, theoretical models to experimental data gathering. He feels that one really doesn't understand something until he has built a general theory of it. He feels that hard data gatherers have a tendency to become so engrossed in collecting data for its own sake that they never get around to putting it all together in some systematic conceptual sense. He also feels that intuitive synthesizers and humanistic scientists both have a tendency to be extremely fuzzy in their thinking. His attitude is that the construction and investigation of formal models and theories produces the best analysis and understanding of scientific problems. In this sense he is extremely critical of speculation that is not tied down and checked by formal reasoning. He is quick to master complicated and sophisticated analytical techniques. He prefers to work on manageable, well-defined problems for which there are available standard, well-developed analytical methods of investigation. He tends to be technique-oriented rather than problem-oriented. In sum, his approach to science is best described as Theoretical-Deductive rather than Empirical-Inductive.

Type C: The Intuitive Synthesizer

Type C is the kind of scientist who first and foremost regards himself as an *Intuitive Synthesizer*. He takes extreme pride in his ability to synthesize and intuit the meaning of

a wide variety of experimental and theoretical facts and ideas. In general, he prefers extrapolation from and speculation on existing data to gathering data of his own. He feels that one doesn't really understand something until he has developed a deep intuitive insight into the basic meaning of that something. He feels that hard data gatherers have a tendency to go on collecting data forever because they lack the basic intellectual or emotional fortitude that would permit them to extrapolate beyond their always limited sets of data. He also feels that abstract theorizers are equally limited, e.g. their overly formalistic ways of conceptualizing phenomena prevent them from appreciating characterization of problems that are not easily, if ever susceptible to formalization. (Humanistic Scientists he tends to dismiss as irrelevant.) His general attitude is that intuition and a global approach produces the best ultimate understanding of scientific problems. This, of course, is a reflection of the fact that his understanding of physical laws and processes is more intuitive than it is formal or even precise. He is quick to formulate and take in broad, sweeping views of problems. He is quick to generate a large number of interesting hypotheses about any problem. He has a high tolerance and even preference for ill-structured problems, the problems that others tend to shun. He tends to be more problem-oriented than technique-oriented. In sum, his approach to science is best described as Intuitive-Synthetic rather than as Theoretical-Deductive or Empirical-Inductive.

Type D: The Humanistic Scientist

Type D is the kind of scientist who first and foremost regards himself as a *Humanistic Scientist*. He takes extreme pride in his ability to perceive the political and moral implication of scientific work and discoveries. In general, he is more concerned with being able to predict the desirable vs. undesirable consequences of scientific products than he is concerned with the details of scientific method that generate the end products. He feels that scientists have been extremely derelict in contributing to the general moral and political understanding of their discoveries. He feels that the hard experimentalists, abstract theorizers and even intuitive synthesizers take too narrow and restrictive an attitude toward science. They are all too preoccupied with the detailed tools and techniques of scientific method, than they are with evaluating the over-all consequences of their end-products. He feels that they are much too insensitive towards the moral and human elements in science. For too long, he feels that scientists have kidded themselves that they could study physical phenomena in a completely detached and objective way. He feels it is high time for scientists to realize that their subjective feelings and emotions deeply affect their so-called "objective" studies and descriptions of Nature. This type of scientist also tends to be more problem-oriented than technique-oriented. In sum, his approach to science is best described as Personally Involved and Evaluative rather than Detached-Empirical-Analytic.

In terms of a seven-point Likert scale where "1" indicated that a portrait "completely represented" a scientist, "7" indicated a portrait "completely misrepresented" a scientist, and "4" indicated a portrait "neither represented nor misrepresented" a scientist, the means of the responses of a sample of forty-two of the Apollo moon scientists are as follows: Type A—3.90; Type B—4.85; Type C—2.85; Type D—4.77. That is, Type C best represents the moon scientists and Type B least represents them. For full details, the reader is again referred to [15].

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