

Artistic Research Tools for Scientific Minds

George W. Ladd

The topics of this paper are frequently-used, versatile research tools: subconscious mental processes (imagination and intuition), chance (including serendipity) and writing. Conditions that may stimulate subconscious mental processes to generate useful ideas are discussed. They are doubt, venturesome attitude, diversity, thorough preparation, tension, temporary abandonment, relaxation, writing, exchange with colleagues, freedom from distraction, and deadlines. Various forms of chance and their roles in research and problem solving are discussed. It is argued that writing is not only a research-reporting tool but is also valuable in performing research.

Key words: chance, imagination, intuition, serendipity, writing.

Two criteria that we teachers apply in selecting topics that we want students to learn are (a) frequency of application and (b) versatility. But, in violation of our own criteria, we pay little attention in our courses to the research tools that are the most versatile and frequently used of all.

The topics of this paper are some frequently-used, versatile tools: subconscious mental processes (imagination, intuition, hunch), chance (including serendipity), and writing. These topics receive little attention in our courses.

On the criteria of frequency of use, consider. In the twenty-three years that I have been doing economic research, I have made six different applications of linear programming. Some applications took a few weeks. Others lasted about a year. If we allow one year per application—a generous figure—we find that in sixteen of the twenty-three years, I have not been using linear programming. But I use subconscious mental processes daily, and write at least weekly, and take advantage of chance whenever I can, which has been more than six times. A similar condition prevails for others with whom I have talked. They use subconscious mental processes and writing more frequently than they use quantitative

tools that they were taught as students, and their careers are affected by luck.

On the criteria of versatility, consider. Linear programming is one of the most versatile tools available to economists. But there are a number of problems for which it is inappropriate. Linear programming has not proved useful for estimating consumer demand functions or for solving truck routing problems. Neither is it useful for obtaining the data needed for a linear program. Each research tool we teach students is, like linear programming, inappropriate for many problems. But subconscious mental processes, writing, and chance are useful for any problem, at every stage of every research project.

Application of the criteria of frequency of use and versatility lead me to conclude that students need to be exposed to the topics of this paper. This paper is addressed mainly to students. But even an experienced investigator who knows the importance of the tools discussed here may find a systematic discussion to be helpful.

Evidence on the usefulness of these tools can be found in books of Austen (a neurologist), Beveridge (an animal pathologist), Hadamard and Polya (mathematicians), Young (a biologist), and Porterfield (a sociologist), and in writings cited in these books. Wiener's (p. 72) first stage in the inductive research process is "the imagination of a theory to fit the facts." Even philosophers of science acknowledge the importance of subconscious mental processes in research. See for example Braithwaite (p. 27) and Popper

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(pp. 31, 32). Hicks' reaction to Keynes' *General Theory* is appropriate here. Hicks wrote:

I must confess that, as I have worked with Mr. Keynes's book, I have been amazed at the way he manages, without the use of any special apparatus, to cut through the tangle of difficulties that beset him, and to go straight for the really important things. He succeeds in doing so just because he makes free use of his superb intuition and acute observation of the real world, in order to be able to discard the inessentials and go straight for the essentials. (p. 4)

Intuition is subconscious. Observation involves the conscious and the subconscious.

The purpose of this paper is to present ways of making subconscious mental processes, chance, and writing more productive.

Subconscious Mental Processes

Have you ever had an experience like this? You are talking and making a point that requires you to talk for two minutes. Halfway through the two minutes you become conscious of a useful idea, but by the time you complete the two minutes of talk you have lost the idea. And you are unable to remember or recreate the idea. Your subconscious mental processes created a suggestion and put it forward for your conscious mind to catch, and your conscious failed to catch and hold the idea.

In the "Born Loser" comic strip of 6 October 1977, Mr. Born Loser is walking along mumbling to himself, "Backward, turn backward, Oh time in thy flight, I just thought of a comeback I needed last night." Perhaps this has happened to you. An hour after an argument, a good idea occurs to you that would have won your case.

These experiences are typical of subconscious processes. The term "subconscious" describes mental processes such as thoughts, ideas, and feelings that occur in our mind without our being conscious of them. Freud's comparison of the human mind to an iceberg illustrates the view held by many psychologists of the subconscious (or unconscious as they call it). Only one-eighth of the mass of an iceberg is above the water; the remaining seven-eighths is below the surface of the water. Only a small fraction of our mental processes are conscious—above the surface of consciousness. A large fraction of our mental processes are below the surface: subconscious (or unconscious) processes.

Normally, we are not aware that our subconscious is operating because the thoughts it throws up to our conscious combine with our conscious thoughts to provide an orderly, reasonable, ordinary stream of consciousness. It is only when the subconscious puts up a new, exciting, extraordinary thought that we are made aware of its operation, or when it puts up a thought on a topic other than the one we are consciously pondering.

Many of our concepts and thoughts originate in the subconscious. Conscious reason is used to examine and accept or reject the proposal from the subconscious.

Given Freud's comparison of the mind to an iceberg and given that ideas originate in the subconscious, it is desirable to increase the productivity of the subconscious. This can be done because the subconscious does respond to stimuli. And a person can exercise some control over the amount, variety, and strength of the stimuli his subconscious receives. By controlling these stimuli, he exercises some control over his subconscious.

It is not enough, however, to stimulate one's subconscious. One must also sensitize one's conscious mind to the operations of the subconscious in order to minimize the number of ideas from the subconscious that are lost before they penetrate the conscious. Some of the things a person does to stimulate his subconscious to create ideas, also stimulate his conscious to grasp the ideas.

Most of the ideas generated by our subconscious processes turn out, upon evaluation by our conscious mental processes, to be useless, or at least useless in the context in which they came to mind. This means that, because the subconscious is often wrong, the person who desires to increase its usefulness must have more ideas, knowing that a large proportion of them will be bad ideas. And he must use his conscious mind to discriminate.

Imagination and Intuition

Psychologists speak of several kinds of imagination. Daydreams and nightdreams are instances of passive imagination. Reproductive imagination is the capacity to form mental pictures of past experiences. The kind of imagination of most concern in science is productive or creative imagination. Senator Robert F. Kennedy is reported to have said, "Some people see things as they are and wonder why. I see things that never were and ask why

not?" To "see things that never were" is an act of creative imagination. The product of creative imagination is a new invention. The new invention may be something physical like the wheel. It may be an artistic piece. It may be a new concept or new idea or new model, (e.g., autoregressive least squares). Frequently the product of the imagination is a link between things that were not formerly seen to be connected in any way. "A thing learned in certain connections is torn out of the context in which it was learned, for use in some new context" (Guilford, p. 100). Ideas, facts, relationships, or concepts become dissociated from their previous contacts and become associated together in new ways.

Porterfield discusses synopsis and synthesis as processes of imagination. Synopsis or "whole-sight" provides a view of the whole of a problem or situation. Synthesis provides understanding of relations among the parts of the whole. Hadamard (p. 23) argues: "The unconscious has the important property of being manifold; several and probably many things can and do occur in it simultaneously. This contrasts with the conscious ego which is unique." Because of the uniqueness of the conscious and the manifold character of the subconscious, the act of synthesis is performed in the subconscious rather than in the conscious. In discussing creative imagination, Weld writes:

Without warning but usually after long incubation and as the result of some chance situation, or some grouping of associative tendencies, a new meaning, a happy thought, is born. . . . In view of the suddenness of its initiation, its unaccountableness, its feeling of strangeness and the joy which it sometimes brings, the new idea often seems to come as an inspiration from on high. Sometimes the new conception comes in its complete form. . . . But at other times and more frequently, the new idea is vague, incomplete or only in outline. . . . (p. 707)

The terms suddenness, unaccountableness, strangeness, joy, inspiration are terms sometimes used to describe intuition. In philosophy, intuition is defined as immediate knowledge attained without conscious deliberation or reasoning. In the theory of knowledge, intuition is the immediate apprehension of truth. It is "knowing without knowing why I know." Beveridge (p. 91) defines it as "a sudden enlightenment or comprehension of a situation, a clarifying idea which springs into the consciousness, often, though not necessarily, when one is not consciously thinking of the

subject. . . . Ideas coming dramatically when one is not consciously thinking of the subject are the most striking examples of intuition, but those arriving suddenly when the problem is being consciously pondered are also intuitions."

We all have these intuitions. Subconscious mental processes are research tools, just as is linear programming, and the subconscious mental processes that create intuitions can be stimulated to be more productive.

Four Stages of Invention

Wallas has described the inventive process as consisting of four stages: preparation, incubation, illumination, and verification.

Preparation is a conscious, voluntary, willful effort that is required to stimulate the subconscious. The rules for the preparation stage include "the whole traditional art of logic, the mathematical forms of which are the logic of the modern experimental sciences, and the methods of systematic and continuous examination of present or recorded phenomena . . . and the voluntary choice of a 'problem-attitude.' Our mind is not likely to give us a clear answer to any particular problem unless we set it a clear question . . ." (Wallas, p. 84).

The incubation stage is a stage of subconscious mental activity. "During incubation we do not voluntarily or consciously think on a particular problem and . . . a series of unconscious and involuntary . . . mental activities take place" (Wallas, p. 86). Illumination is the same as Beveridge's "sudden enlightenment or comprehension."

Wallas discusses verification as a conscious, voluntary, willful effort. It is guided by the same rules as preparation. One purpose of verification is to test the illumination against logic or mathematical rules, experience, and other knowledge. Another purpose is to express the results in language. A third purpose is to "precise" the results, that is, to state the results completely and precisely. A fourth purpose is to prepare for using the illumination. What Wallas calls verification, some people would call verification and validation.

Typically a person is simultaneously engaged in two or more of these stages on two or more problems. Conscious verification of an answer to one problem is preparing him for subconscious effort on a second problem while his subconscious is incubating on a third

problem. Work on any single problem does not follow these steps in strict sequence. Rather, investigators jump back and forth from one step to another.

Conditions Stimulating to Subconscious Mental Processes

Reading, discussions, and introspection lead to the belief that many people's subconscious minds respond to the stimuli discussed here.

Doubt

In those instances when you are most doubtful of accepted modes of thought or of conventional questions or approaches, your subconscious is more apt to generate novel ideas than when you are satisfied with the conventional wisdom.

Venturesome Attitude

You are not going to break ground by developing something new if you are paralyzed by the fear of making a mistake. Don't be afraid to make mistakes. There are plenty of people around who will delight in pointing out your errors. Think how much pleasure you will afford those people if you do make a mistake! I think it was John Maynard Keynes who astutely observed, "It is not so terrible to make a mistake. What is terrible is not to be found out." By the time each of us finishes formal schooling, he has been caught in enough mistakes that he knows that being found out does not destroy one's ego or self-esteem. Being caught in a mistake after leaving school is not more destructive of one's self-esteem than being caught in a mistake while in school.

Probably fear of failure also inhibits us. But, if a failure now and then is going to ruin your career or your self-esteem, your successes must not be worth much. Perhaps this suggests a career that is a mixture of some "safe" projects and some "risky" projects so that successes on the "safe" projects can compensate for possible failures on the "risky" projects. But failure is unpredictable. On some projects you will fail to achieve what you initially thought were modest objectives. In some cases you will achieve objectives that you initially had no idea how to achieve.

One reason for this may be some sort of compensatory principle. A greater curiosity

about or interest or challenge in the risky project elicits more preparation and effort. Too, a magnificent failure can be more exciting than a modest success.

Few things in life are more gratifying than accomplishing a task that you once believed to be impossible. It is appropriate to recall that Pogo (in Walt Kelly's comic strip of the same name) once observed, "We are confronted with insurmountable opportunities."

Diverse Experiences, Memories, and Interests

One condition favorable to a fruitful subconscious is diversity of memories, experiences, and interests. A fruitful intuition is often the perception of a connection between things that were previously unconnected. A varied store of memories and experiences makes it possible for your subconscious to perceive connections between things that you would not even be aware of if your experiences were less varied. One of the advantages an experienced investigator has over a young researcher is that the former has a more varied store of memories and experiences to draw on.

From his studies of problem solving, the psychologist Raaheim has concluded, "The more experienced you are, the more problems you are likely to be faced with. And . . . the more problems you are likely to solve" (p. 87).

The diversity need not all be in professional interests and experiences. Austen emphasizes that research results are the accomplishments of the whole person, not just of a compartmentalized "professional" portion of a person, and presents examples to show that his hobbies of music, watercolor painting, and hunting have contributed to his research in neurology. A person can acquire diverse experiences vicariously by reading on a variety of topics. Mighell argued that economists should read widely.

Variety in experience does not come simply from living. You must make an effort to obtain it. A young assistant professor had failed to make this conscious effort. He had been at one school for three years when he learned that a desirable position was open at another university. He quickly applied for the position. In his application, he emphasized the benefit of his three years of experience. His department head, however, saw it differently. In his letter of reference he wrote, "This young man claims to have had three years of experience.

This is not so. He has had one year of experience three times.”

Thorough Preparation

Preparation precedes subconscious mental activity. The more thoroughly your conscious mind has grasped the problem—in general outline and in detail—the better is the chance that your subconscious will produce fruitful ideas. Subconscious processes are stimulated by vigorous conscious processes.

How does one go about preparing thoroughly? Some relevant considerations were presented under the section, “Four Stages of Invention.” Careful formulation of the problem is an important part of preparation.

Tension

Conscious absorption of a problem, teamed with an intense desire to know, provides a strong stimulus to your subconscious. In discussing the creative person, Maslow (p. 47) has written of “this total fascination with the matter-in-hand, this getting lost in the present, this detachment from time and place.” Such total immersion in a problem bespeaks of intense concentration and overpowering desire for a solution. The stereotype of the absent-minded professor has a factual basis in the actual behavior of professors experiencing “this detachment from time and place” while in the throes of “tense thought,” to use Hadamard’s term.

What are sources of a strong desire for a solution? One is certainly curiosity. It seems to me that curiosity has an aesthetic component: an intellectual aesthetic sense, or a yearning for intellectual tidiness. Beveridge (p. 77) wrote of the “love of order and logical connection between facts.” Polya (p. 45) expressed it, “The feeling that harmonious simple order cannot be deceitful guides the discoverer both in the mathematical and in the other sciences.” An aesthetic tension is created by an incomplete or broken pattern of facts and ideas or a pattern with discordant pieces. This tension is discomforting. When you finally see the pattern complete and unbroken, you experience a delightful release of the tension. You perceive something soothing or delightful to your sense of intellectual aesthetics. Curiosity may also have a component

of the naive, open-eyed wonder of a child at the marvels of the world. Another source of strong desire for a solution may be your ego. Obtaining a solution gives you a sense of mastery. Your desire for a solution may rise from a feeling of frustration: frustration with the inadequacies of present answers to a question, or irritation over the lack of an answer.

Temporary Abandonment

A practice that most people find favorable to subconscious activity is temporary conscious abandonment of the problem. Upon returning to the problem later, one frequently finds that he has acquired new ideas or insights in the interim. One undesirable result of over-long conscious pondering of a problem is conditioned thinking. Conditioned thinking is like cycling in solving a degenerate linear program: the mind continually retraces the same established (and fruitless) patterns of thought. Temporary abandonment helps to break these fruitless patterns. The value of temporary abandonment is reflected in the old proverb, “Sleep on it.”

The essence of Wallas’ second stage in inventive thought—incubation—is temporary conscious abandonment. You may also temporarily abandon a problem during the preparation stage. You may alternate between conscious thought and temporary abandonment several times before finally coming up with a solution.

One student working on his dissertation told me that when he was having difficulty, he would concentrate on the problem for the last fifteen to thirty minutes of his evening’s work before going home, and then not think about the problem any more that evening. The problem frequently would be clarified, and sometimes solved, by the time he returned to his office the next morning.

A colleague has told me that he works most effectively when engaged in intense concentration if he takes a five-minute break every half-hour. During that five minutes he may take a coffee-break or walk to the water fountain for a drink. After the five-minute break, he returns to work refreshed.

You may temporarily abandon conscious efforts on one problem in order to turn your conscious mind to other problems. But you may also temporarily abandon conscious efforts on all research.

Relaxation

Some people find a period of relaxation or light effort—driving, shaving, walking—immediately following a period of serious effort to be a favorable time for intuitions. The subconscious processes of some people are active at night, and these people will be awakened during the night by bright ideas, or ideas will spring to mind just after waking in the morning. Some people find lying in bed in the morning while half-awake to be favorable to the appearance of intuitions. Some people find a combination of mental relaxation and physical exercise to be conducive to the appearance of intuitions.

Writing

Young expressed the attitude of many people toward writing when he wrote, "The scientist does not usually think of the writing of books or preparing of lectures as research. Writing seems to him to be a rather tiresome labour that he must do after the fun of laboratory research is over" (p. 1). But, later in the same paragraph that contained this statement, Young wrote "I came to realize the extent to which having to describe the results of one's thoughts to others is a part of the process of discovery itself."

Many of my intuitions come to me when I am writing. It frequently happens that "I don't know what I think until I write it." It sometimes happens, for example, that I start to write a paragraph knowing only the first sentence and having only a vague idea of the central theme. But by the time I reach the end of the paragraph I will have expressed some ideas that I did not have when I started the paragraph, or at least did not know I had.

Clardy beautifully expresses my attitude toward writing. She says, "I have acquired many things by writing them. There are allegedly those who know what they have to say before saying it, but I have never counted myself in their number. Argument seems to me a means of developing rather than merely demonstrating theories, and articulation a means of amassing rather than just disseminating insight. Writing is as much the cause as the result of having something to say."

The process of learning from your own writing does not end at the first draft. In discussing rewriting and restating the evidence, Penfield (p. 106) states, "often, once I get my thoughts

truly expressed, I see things I never suspected before."

Precising the results and preparation for using the illumination are two purposes of the verification stage of invention. Precising the results involves stating them completely and precisely writing them. The writing helps you to prepare to use the results.

We usually think of writing as something that one does to report to others. What is being advocated here is writing to yourself to generate or discover knowledge. This position is similar to the one you have probably heard (and may have expressed yourself): "The best way to learn something is to have to teach it." For some statistical support for this view, see Siegfried. He concluded that proctoring an introductory economics course significantly improves the student-proctor's understanding of economics principles.

Exchange with Colleagues

Discussion with others can be helpful in various ways. Your colleagues' or students' comments can bring out points you had missed. They may bring a new perspective that provides you with new insight. They may point out an incorrect assumption you were making, and show you a correct alternative. They may complete a partial idea of yours.

Discussion has other values. Keynes wrote (p. vii): "It is astonishing what foolish things one can temporarily believe if one thinks too long alone. . . ." Discussion with colleagues provides a useful defense against believing foolish things. Take care, however, lest your colleagues teach you foolish things that you did not know before.

Some people find the most stimulating exchange with colleagues to be the exchange that occurs in a "pressurized environment," as when presenting and defending a paper before a friendly but critical audience. These people commonly say "I think better on my feet."

The difference between "writing" and "exchange with colleagues" is that writing represents an exchange with one's self.

Freedom from Distraction

Another condition favorable to the subconscious is freedom from distraction: interruption by others, intrusive noises, pressures to be working on several other jobs in addition to the one currently occupying you. Intrusive

influences that distract your conscious mind inhibit the operation of your subconscious mind. These influences also make it more likely that ideas generated by your subconscious will be overlooked by your conscious.

It is a common experience that putting in eight hours on research in two four-hour stretches is more productive than eight one-hour stretches. The reason may be that changing tasks requires redirecting your subconscious. Changing from one task to another shortly after the first task is initiated requires your subconscious to be redirected before it has time to accomplish anything on the original task.

In addition, frequent changing of tasks makes it difficult for your subconscious mind to absorb thoroughly any single problem. You might say that prolonged concentration on one problem permits the conscious to transmit information to the subconscious. When you change tasks frequently, the messages transmitted from your conscious are received by your subconscious as random noise.

Both temporary abandonment and distraction mean changing the course of your conscious thoughts. One is voluntary and the other is involuntary. If you do it to yourself, it is temporary abandonment. If I do it to you, it is distraction.

Deadlines

Some scientists do their best work when facing deadlines imposed from outside. For deadlines to have this effect, you must be able to work without distraction. It is questionable whether self-imposed deadlines do stimulate the subconscious. Such deadlines so easily can be set back by a few days or a few weeks.

The conditions most stimulating of all to your subconscious are those that combine a number of the individual conditions presented here, e.g., interdisciplinary brainstorming sessions in preparation for writing a report due the fifteenth of next month. This involves diversity, exchange with colleagues, and pressure of meeting a deadline.

Capturing Intuitions

It does you no good to have a fertile subconscious if your conscious fails to grasp the results of your subconscious processes. Intuitions frequently appear on the edge of your conscious and willful effort is required to

grasp them before they are lost. You need to be alert to grasp these intuitions as soon as they appear. Commonly an intuition lost once is lost permanently. Some people wisely make a habit of jotting down notes as soon as an intuition appears.

Chance

Beveridge has written, "New knowledge very often has its origin in some quite unexpected observation or chance occurrence arising during an investigation. The importance of this factor [chance] in discovery should be fully appreciated and research workers ought deliberately to exploit it" (p. 55). And the mathematician Polya writes: "The first rule of discovery is to have brains and good luck" (p. 172).

Nelson (p. 256) reports:

After he discovered the tuberculosis bacillus [Pasteur] was very often given evidence of the acute jealousy of people in his or in related fields. At a big reception at which Pasteur was the guest of honor one of his colleagues came up and said, "Isn't it extraordinary these days how many scientific achievements of our century are arrived at by accident?" Pasteur said, "Yes, it really is remarkable when you think about it, and furthermore, did you ever observe to whom the accidents happen?"

Pasteur's response becomes more meaningful if you know that Pasteur believed that "Chance favors only the prepared mind."

Four Forms of Chance

Austen finds four kinds of chance that play roles in creative research. Chance I represents blind luck, completely accidental. In Chance II, good luck is the result of general exploratory behavior. Its major premise is that "un-luck runs out if you persist" (p. 73). Its main feature is general exploratory actions in promising directions. In Chance III, good luck is the result of personal sagacity. It occurs to the "prepared mind" when "some special receptivity born from past experience permits you to discern a new fact or to perceive ideas in a new relationship" (p. 78). Austen classifies Chance I, II, and III as serendipity, "the facility for encountering unexpected good luck as the result of accident, sagacity or general exploratory behavior" (p. 71). Chance IV "is the kind of luck that develops during a probing action that has a distinctive personal flavor"

(p. 75). Chance II involves generalized motor activity. Chance III involves one's personal sensory receptivity. Chance IV involves personalized motor behavior (action) that is focused in a specific manner that results from the investigator's own unique combination of skills, interests, background, aptitudes, personality, values, beliefs: from the person the investigator is. Austen's classification can make you aware of the different ways that chance can benefit your research and can thereby increase the likelihood that you will recognize those situations when you can be the beneficiary of chance.

The results of chance are not all beneficial in research; results of chance can also be harmful. The existence of "Murphy's Laws," their correlatives and variations are evidence of the awareness of the negative effects of chance. Austen (pp. 95-96) presents twenty such laws. The simplest version of Murphy's Law is, "If anything *can* go wrong, it will."

You do have some control over your luck. You cannot determine, but you can influence, your luck. Possession of a lively curiosity, active imagination, acute perception, diverse experiences, a retentive memory, and persistence will do a great deal to improve your luck.

One Solution Solves Several Problems

In one sort of serendipity, a method used to solve one problem turns out to be appropriate for solving a second problem that was not previously perceived as having any relation to the first; or a solution to one problem turns out to be a solution to an apparently unrelated problem. This justifies Polya's advice (p. 65): "Having made some discovery, however modest, . . . we should not miss the possibilities opened up by the new result, we should try to use again the procedure used. Exploit your success! *Can you use the result, or the method, for some other problem?*"

Polya's suggestion would worry some economists. These people are concerned that "too many agricultural economists are tool-oriented rather than problem-oriented. They learn a method or tool and then search around for problems to try it on." I think Polya's proposal is justified, and their concern is justified. These economists are concerned, I believe, about people practicing cookbookery or mathematistry, in Box's terms. The symptoms of cookbookery are "a tendency to force all

problems into the molds of one or two routine techniques, insufficient thought being given to the real objectives of the investigation or to the relevance of the assumptions of the imposed methods" (p. 797). "Mathematistry is characterized by development of theory for theory's sake, which since it seldom touches down with practice, has a tendency to redefine the problem rather than solve it" (p. 797). It is possible to follow Polya's advice without engaging in cookbookery or mathematistry.

Hadamard (p. 50) lamented his missed opportunities when he "happened to overlook results which ought to have struck me blind." Following Polya's advice will reduce the frequency with which you miss opportunities to use your discoveries.

Problem Solving

It will give us greater insight into the various forms of chance if we consider some findings of psychologists on problem-solving behavior. Raaheim differentiates among three kinds of tasks. He first conceives of a series of earlier situations of the same sort. A problem situation is "the deviant member of a series of earlier situations of the same sort" (p. 22). The definition focuses at once on the elements that are common to the problem situation and the earlier situations, and the difference between the problem situation and the earlier situations. This definition treats as problems those "tasks which may eventually be solved by *intelligently* utilizing one's past experience" (p. 50), because intelligent behavior depends on an ability to reformulate one's past experience to meet the requirements of the present.

A second kind of task is a routine task. A routine task has no detectable difference from previous situations of the same sort. Solution of such tasks does not require application of intelligence, but use of memory.

The third kind of task is a novel task in which "the deviation from what are the familiar features is too great . . . when a familiar pattern is no longer recognizable" (Raaheim, p. 83). Intelligence is not a factor in solving such totally unfamiliar tasks. Application of intelligence to solution of such tasks can delay or even prevent finding a solution. "For the effective handling of very unfamiliar tasks, an exploratory activity is more rewarding than intelligent reflection" (Raaheim, p. 84). In experimental studies of people faced with novel

tasks, the successful experimental subjects were more active, more persistent, and tried out more methods of attacking the task than the subjects who failed to solve the novel task. This categorization of tasks helps us to see one of the benefits of experience. What is a novel task to a novice may only be a routine task to an experienced person.

This categorization also implicitly focuses on the characteristics and experiences of the decision maker involved. For example, academic economists and businessmen face different sets of tasks. The same decision-situation that presents a businessman with a problem because it deviates somewhat from a series of earlier, similar situations would present an academic economist with a novel task because he has experienced no earlier, similar situations.

Chance in Solving Problems

Chance II and IV involve movement, action, trying, persistence: things that are important in solving novel tasks. In facing a task, one thing you do is search for a series of similar situations that have been encountered earlier. This may involve attempts to form different series and attempts to reformulate some past experiences. In carrying out these activities, you are liable to do a good deal of searching (of memory, notes, books, journal articles, of colleague's ideas, and experience) and some trial and error. This involves the motion of Chance II and Chance IV. And the prepared mind and ability to form significant associations of Chance III can have a deciding effect on the success or failure of the quest.

Writing

Many people look upon writing as purely a research-reporting tool; they neglect its role as a research tool. Everything presented earlier on writing as a stimulus to the subconscious argues that writing is a valuable research tool. Certainly if you share with me the trait of not knowing what you think until you write it down, you should view writing as a research tool. Writing serves other functions in addition to stimulating the subconscious. Writing out in detail the statement of the problem, how you plan to solve the problem and why you plan to solve it in the way you do, can save work, time, money, and embarrassment.

Preparing a report covering statement of the problem, review of literature (if appropriate), theoretical analysis (economic, statistical, econometric, or operation research), data used, method of data collection, method of empirical analysis of the data—everything but results, summary, and conclusions—before beginning to collect and analyze data has several beneficial results. It causes you to solve many problems before they ever arise, and to solve them in a consistent, coherent way. It reduces the collection of unnecessary data, likelihood of failure to collect needed data, number of false starts, and performance of unneeded computations.

An alternative to writing before doing research is to do and decide simultaneously: while doing research you are also deciding how to do research. A common result is that doing gets ahead of thinking and when you finally begin to think about what you did last week, you discover that you did it wrong and last week's work has to be redone. Access to electronic computers handicaps the student, or any other researcher, who tries to plan research and perform research simultaneously. If you try to keep the computer busy, and many seem to feel the need to do so, your own busyness keeps you from doing adequate planning.

A common objective of research is the testing of hypotheses. Before you ever start testing, you ought to know which hypotheses you will test, how you will test them, why you will test them, and how you will interpret results of the tests. Writing a report before doing the research increases your chances of knowing these things and, consequently, of correctly performing and interpreting the tests of hypotheses that are most relevant for your problem. Every research project involves use of maintained hypotheses, i.e., of things that are assumed to be true for the purposes of, and during the duration of, the study. Sometimes the question of whether a specific hypothesis should be tested or maintained is critical. You are more apt to make a proper choice if you write before you act.

A reason for having my students write their theses before doing their research is this. When public funds have been assigned to me and I am responsible for them, and a student is spending those funds to gather data or perform computations, I am not comfortable unless I know what he is doing and am confident that he knows what he is doing.

Austen (p. 171) presents another reason for doing the writing before the research is completed. He writes, "The investigator must finally put all the information into a manuscript for publication complete with tables, figures, and bibliography, and must try to anticipate which editors of which journals will be the most receptive. By now, . . . months have gone by. The original ideas have lost their luster. Completing the manuscript is like giving birth to a cactus that has bloomed long before." Writing is much less painful if done as an early step in research than if left to the end.

Reasons Most Courses Ignore These Tools

Why do the research tools covered here receive so little attention in our graduate programs? This section represents my (speculative) explanations.

First, special purpose research tools (multiple regression, linear programming, etc.) are "public property." They are in the public domain. The tools discussed in this chapter are "private property." They are in the private domain. Thus, you can discuss my linear program or regression analysis as well as I can. And I can discuss yours as well as you can. But you cannot study and discuss my subconscious mental activities or writing habits. Nor can I study yours.

Logical analysis is public property (we all know and use the rules); intuitive analysis is private. One consequence is that "scientific types tend to downgrade subconscious mental activities because they try to keep things 'rational, within reason' (that is, consciously workable)" Austen (p. 162).

Perhaps a more fundamental reason relates to differences between the left and right halves of the mind. Austen (pp. 138-39) reports:

Our left cerebral hemisphere 'thinks' in verbal, auditory terms, is good at translating symbols, including those of mathematics as well as language, and works best when analyzing a sequence of details. . . . In contrast, our right hemisphere 'thinks' in visual, non-verbal terms, particularly in terms involving complex spatial relationships, and specializes in three dimensional depth perception. It also recognizes structural similarities, and works best in Gestalt: that is, drawing conclusions based on a grasp of the total (visual) picture. . . . While its left partner proceeds, piecemeal, to examine the irregular bark on each tree, our right hemisphere grasps in one sweep the shape of the whole forest, relates it adroitly to the contours of

the near landscape, then to the line of the horizon. . . . Hidden away, almost out of reach of language [in the right hemisphere], can be the source of intuitive insights that are of fundamental importance in solving a problem. And this hemisphere . . . is mute.

We see that education addresses itself almost entirely to the left half of the brain. Scientists tend to be "outward-oriented" rather than "inward-oriented." They ask, "how does the world out there work?" and not, "how does the world inside me work." As individuals, they may be curious about the latter question; but they view this as an individual concern, not a scientific concern. Related to this is the scientific constraint that research reports are to focus on the investigation, not on the investigator.

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