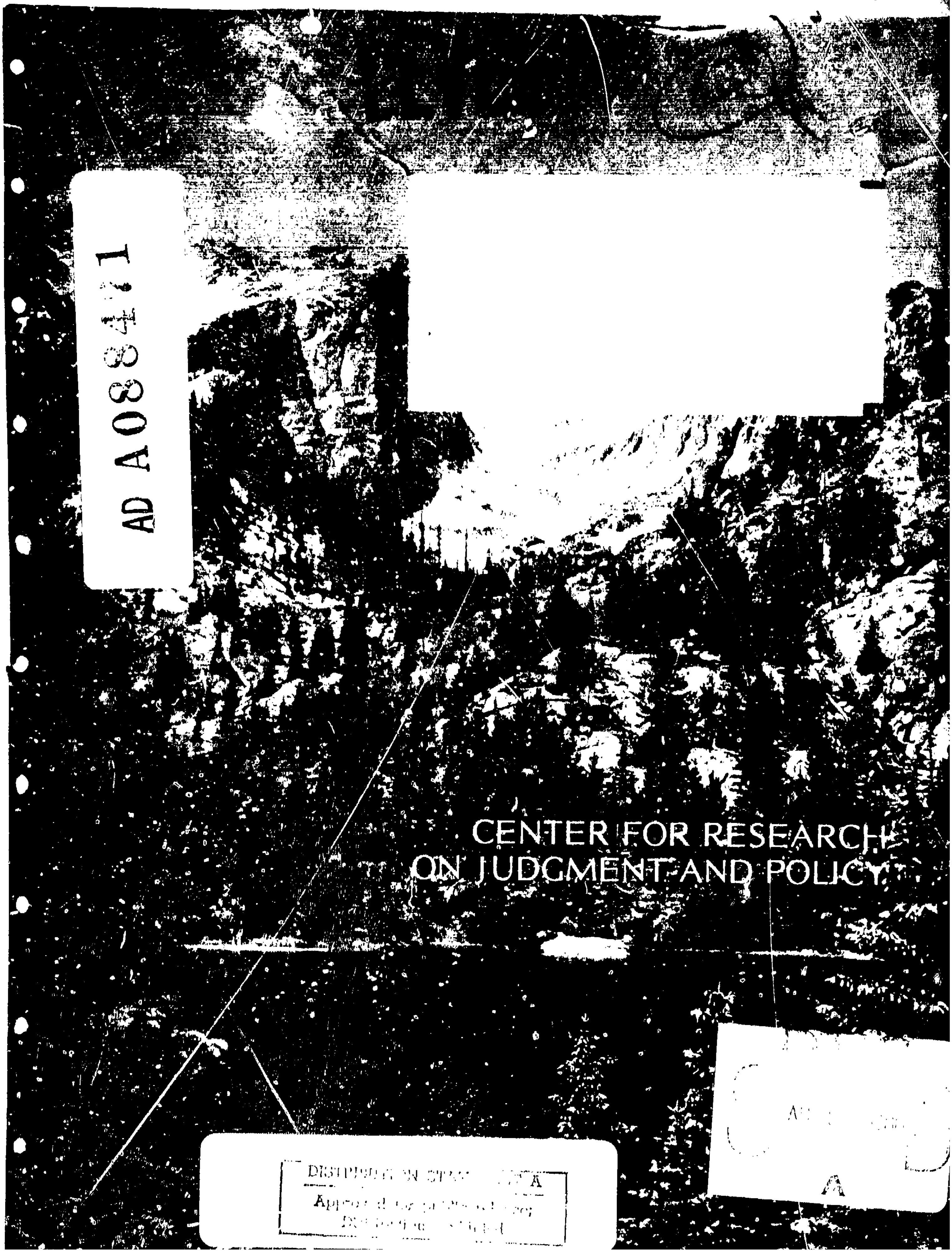

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THE INTEGRATION OF RESEARCH IN JUDGMENT AND DECISION THEORY

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The five major premises of the Cognitive Continuum Theory of judgment and decision making are described and the potential power of the theory to encompass and to unify the work in the field of judgment and decision making is indicated. Because the theory is anchored in the concepts of intuitive and analytical cognition the recent treatment of these topics is described in terms of (a) the positive view, in which intuitive cognition is praised for its special capabilities to accomplish what analysis cannot,

410647

and (b) in terms of the negative view, in which intuitive cognition is denigrated for its failures, "shortcomings and distortions"; in short, for its inability to accomplish what analysis can. In contrast to both views, the Cognitive Continuum Theory puts forth a "comprehensive view"; it provides a means for encompassing cognitive tasks, cognitive activities and their behavioral and adaptive consequences over the full range of cognition. This leads to the examination of the various properties of the many different cognitive tasks that are encountered by contemporary human beings, as well as examining the properties of the cognitive activities induced by such tasks and the judgment and decision making behavior that follows. Various properties of cognitive tasks are therefore listed, the various properties of cognitive activites that are associated with these task properties are indicated, and predictions are made regarding the behavior that follows from various cognitive activities. The central role of time in all studies of cognition is deemed to be so important that it is given separate treatment. And the convergence of the major concepts of the Continuum Theory with the recent results of brain research that focuses on the lateralization of structure and function are discussed.

The Integration of Research in Judgment and Decision Theory

Kenneth R. Hammond

Judgment and decision research occupies the middle range of the field of cognition. Research on problem-solving and thinking provides a boundary on one side; studies of social perception provide a boundary on the other. These are uneasy boundaries in that it is often uncertain exactly where they lie, how permeable they are, and to what extent the neighbors should be interested in what is going on over the fence. The first step toward the integration of the field of judgment and decision research reached out toward these boundaries with its construction of a theoretically neutral framework that would allow, and thus encourage, description and comparison of various approaches. This step was accomplished with the publication of "Human Judgment and Decision Making: Theories, Methods and Procedures" (Hammond, McClelland, & Mumpower, 1980). A second step is being taken with the preparation of a "Glossary of Terms Used in Judgment and Decision Research," to be published in 1981, by Anderson, Hammond, McClelland and Shanteau.

The present report constitutes the third step toward the goal of integration; it presents a theory of cognition within which each approach to that topic has a special, identifiable place and function, and thereby makes its special contribution without replacing others. Such a unifying theory is in sharp contrast to a replacement theory, i.e., a new theory which replaces, or "overthrows" a theory currently held. A unifying, rather than a replacement, theory is required for the field of judgment and decision research because it is so amorphous that a replacement theory could hardly succeed: no single theory or approach so dominates the field that its demise would be a crippling event. And although the advocates of various theoretical approaches have no doubt gratuitously over-generalized their findings to domains beyond their scope (as all theorists must), no approach seriously argues that its conceptual framework is so broad (and so demonstrably successful) that it should replace all others.

The goal of the unifying theory to be presented here is, therefore, to make it possible for various approaches not only to be seen in relation to one another, but whenever possible, to become mutually supportive. If such a theory were to be successful, it would result in the incorporation rather than the abandonment of rapidly accumulating research results, so many of which are now being submerged in the archives for the lack of a theoretical lifeline. Unification, then, is the aim of the theory to be presented, and advocated, here.

In order to achieve this goal I shall try to meet Popper's requirements for a unifying theory: "The new theory should proceed from some <u>simple, new, and powerful unifying idea</u> about some connection or relation (such as gravitational attraction) between hitherto unconnected things (such as planets and apples) or facts (such as inertial or gravitational mass) or new 'theoretical entities' (such as field and particles)" (1963, p. 241). In his endorsement of these requirements Bronowski indicated why unifying ideas are attractive: "We want to feel that the world can be understood as a unity, and that the rational mind can find ways of looking at it that are simple, new and powerful exactly because they unify it" (1977, p. 101).

Such a goal is an ambitious one for the rather new field of judgment and decision research; but it is not an idiosyncratic goal; it is important to the closely related field of memory research as well, as the following quotation from a review of "Perspectives in Memory Research" illustrates: "the overriding impression the reviewer is left with is that the field is diverging at an unprecedented rate and that the prospects of theoretical unification have never been more remote" (Watkins, 1980, p. 756).

I begin by describing five premises which serve as the basis of the Cognitive Continuum Theory that aims at unification.

FIVE PREMISES

First, various modes, or forms, of cognition can be ordered in relation to one another on a continuum that is marked by intuitive cognition at one pole and analytical cognition at the other, in contrast to the traditional dichotomy, or antinomy, that has been posited between these modes of cognition.

Second, forms of cognition that lie on the continuum between intuition and analysis include elements of both intuition and analysis and are included under the term quasi-rationality. It is the most common form of cognition, is known to the layman as "common sense," and is related to Simon's concept of "bounded rationality."

Third, the properties of cognitive tasks permit them to be ordered on a continuum with regard to their capacity to induce intuition, quasi-rationality and analysis. Thus, an a priori relation can be specified between the properties of cognitive tasks and the modes of cognition induced by them.

Fourth, cognitive activities move along the intuitive-analytical continuum over time; as they do so the relative contributions to cognition of intuitive and analytic components of quasi-rationality will change. Successful cognition inhibits movement, failure stimulates it.

Fifth, intuition, quasi-rationality and analysis are cognitive functions that have structural counterparts in the brain.

Explanation of Premises

Premise 1

Various modes, or forms, of cognition can be ordered in relation to one another on a continuum that is identified by intuitive cognition at one pole and analytical cognition at the other.

The idea of a cognitive continuum runs counter to the traditional absolute distinction drawn between intuition and analysis, and the competition between them. This dichotomy can be found throughout the history of man's epistemological efforts (see, for example, any history of philosophy), but a striking, modern account of the recent (17th century ff.) distinction between them can be found in Isaiah Berlin's work, where intuition and analysis are described as "rival forms of knowing" (1978). Moreover, the absolute distinction and competition between them has long been emphasized in science, where intuition has been identified with creativity and the pictorial representation of ideas, in opposition to empiricism and the analytical modes of logic and mathematics. The consequences of the opposition of these modes of cognition can be seen in the introduction by J. Wechsler to an essay by Arthur Miller in "On Aesthetics in Science" (Wechsler, 1978):

> Arthur Miller introduces in his essay a new approach to the development of quantum theory, emphasizing the drama and the force of imagery and metaphors in the development of a theory of atomic phenomena. Aesthetic judgments played a major role in this period--an aesthetic of waves and/or particles and the choice of a mathematical formalism. Whereas Heisenberg's mode of thinking committed him to continue to work with a corpuscular-based theory lacking visualization, Bohr, Born, and Schrodinger believed otherwise; their need for the customary intuition linked with visualization was strong. Heisenberg's reply was that a new definition of intuition was necessary, linking it with the mathematical formalism of his new quantum mechanics. Visualization was regained through Bohr's personal aesthetic choice of the complementarity of wave and particle pictures, thereby linking physical theory with our experiences of the world of sensation. What is so remarkable about this period is that the intense struggle between these physicists surfaced in their scientific papers. (p. 72)

The persistent conflict between scientists who employed different modes of cognition in the history of science is documented in detail by Holton (1973), but the contrast between contemporary scientists is vividly illustrated by Freeman Dyson in his description of his dialogues with his colleague, Nobel prize-winner Richard Feynman:

> The reason Dick's physics was so hard for ordinary physicists to grasp was that he did not use equations. Since the time of Newton, the usual way of doing theoretical physics had been to begin by writing down some equations and then to work hard calculating solutions of the equations. This was the way Hans and Oppy and Julian Schwinger did physics. Dick just wrote down the solutions out of his head without ever writing down the equations. He had a physical picture of the way things happen, and the picture gave him the solutions directly, with a minimum of calculation. It was no wonder that people who had spent their lives solving equations were baffled by him. Their minds were analytical; his mind was pictorial. (Dyson, 1979, p. 55-56)

Note how the distinction between intuition and analysis is cast into "rival" forms of knowing by Berlin, into a "struggle" by Wechsler, and how Dyson deepens the distinction by asserting that scientists whose "minds are analytical" are "baffled" by those whose minds are "pictorial." These comments illustrate the common expression of an antinomy between these modes of cognition in contrast to the continuum that is presented here.

But a striking, and perhaps unique, illustration of the intuitive-pictorial mode of cognition appearing together with the analytical-verbal mode may be seen in the diagrams from Darwin's notebooks, presented in Figures 1 and 2. Gruber searched out these diagrams during his analysis of Darwin's creation of the theory of evolution (Gruber, 1974, 1980;). Gruber, a close student of scientific creativity, provides these comments on Darwin's diagrams:

> In the Origin of Species there is only one diagram, one guiding image--the "tree of life" depicting the theoretical model of branching evolution referred to repeatedly throughout the Origin (p. 141). . . . Darwin was able to use even his first crude version of the tree schema to produce further deductions (italics mine). He sees immediately that the branching tree model accounts for certain discontinuities in nature. (1974, pp. 142-143)

Gruber then emphasizes Darwin's use of analytical cognition by observing that Darwin "stresses the point that conserving the number of species requires extinction and explores in a quasi-mathematical form (italics mine) the amount of divergence" (1974, p. 144).

Examination of Darwin's visualization, his pictorial image of evolution described by him as what "I think" in the upper left hand

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Figure 1 here

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corner of his diagram), together with his analytical-verbal deduction (indicated by the underlining of "requires" in the upper right hand side) thus provides us, thanks to Gruber's perspicacity, with a marvel of cognition: intuition and analysis are joined on the very same page in one of man's greatest cognitive achievements.

Summary. Premise One is the essential element of a unifying theory. Shifting from the idea of dichotomous, competing forms of cognition to the idea of cognition as a continuum makes it possible to see cognition in a variety of forms which various researchers have selected for study. It now remains for us to work out the details of the relation of these forms to one another, particularly in the area of human judgment and decision making. This brings us to Premise 2.

Premise 2

Forms of cognition that lie on the continuum between intuition and analysis include elements of both intuition and analysis and are included under the term quasi-rationality. It is the most common form of cognition, is known to the layman as "common sense," and is related to Simon's concept of "bounded rationality."

The explanation of Premise 2 requires first the clarification of the meaning of its critical terms: analysis, intuition and quasi-rationality; the analytical-intuitive distinction is treated first.

The meaning of analysis or analytical thought in ordinary language is clear; it signifies a step-by-step, conscious, logically defensible process of problem-solving. The ordinary meaning of intuition signifies the opposite, a cognitive process that somehow permits the achievement of an answer, solution, or idea without the use of a conscious, logically defensible, step-by-step process. Analysis has always had the advantage over intuition in clarity of meaning because its meaning could be explicated by the overt reference to a logical and/or mathematical argument or model; moreover, analytical thought is the basis of rationality; rational argument itself calls for an overt, step-by-step, defensible process. Thus, analytical thought and overt definition are part of the same system of thought. Not so with intuition; throughout its history it has acquired a mystique, an ineffable, undefinable character. Because this concept has received only episodic treatment in the literature, we are fortunate that in 1967 Westcott provided an excellent historical review and thoughtful analysis of the concept of intuition.

Westcott reviews first the history of intuitionism in philosophy and then traces its history in psychology. His treatment of the concept of intuition in the study of social judgment and decision making is restricted to the work by Bronfenbrenner, Harding, and Gallwey (1958), Bruner (1957; 1966) and others, including Cline and Crutchfield, as well as the literature in clinical judgment up to 1967 (including the work of Meehl, Oskamp, and Sarbin); none of the work on behavioral decision theory or Brunswikian research is referenced, however. As a result, there is almost no overlap between Westcott's review and Slovic and Licthenstein's 1971 review which appeared only four years later.

Westcott concludes his chapter on "Psychological Concepts of Intuition" by observing (p. 52) that "The term 'intuition' continues to appear in works of all kinds--used precisely or loosely, with or without acknowledgement of sources." That observation can be repeated with assurance today. For example, Westcott notes (p. 39) that "In Bruner's work (1961) . . . concerned with education, the term 'intuitive thinking' is indexed 24 times." Wescott indicates that, despite its prominence, Bruner provided no clear definition of his use of the term, although Wescott does note that, "Probably the single definition which encompasses the bulk of his uses is: 'the intellectual technique of arriving at plausible but tentative formulations without going through the analytical steps by which such formulations would be found to be valid or invalid conclusions'."

If Westcott believed these circumstances to be unsatisfactory in 1967, he would find that matters have changed little, or become worse, for a similar result can be found in a recent review of work in attribution theory and judgment and decision research by Fischhoff (1976) in which the word intuitive (or intuition) appears 22 times in a 24-page chapter, yet does not receive definition. The centrality of the word is indicated by the fact that Fischhoff uses it in his opening paragraphs to contrast research in attribution theory with research in judgment theory, thus: "Kelley (1973) compares man to an intuitive scientist; in a central article on judgment research, Slovic and Lichtenstein (1971) seriously question the notion of man as an intuitive statistician" (p. 421). The pervasiveness of the term in the judgment and decision literature is indicated by the fact that neither the word "intuition" nor "intuitive" were indexed.

Wescott's review makes clear the fact that the concept of intuition has played a central, pervasive, but uncertain and ambiguous role in the history of the study of cognition in psychology. For whereas the concept of analytical cognition has always benefitted from having a standard in some normative theory or model of cognition (e.g., Mill's Canons, statistical logic) from which it can depart, intuitive cognition has not had the benefit of any overt, agreed-upon anchors. As a result, the forms toward which intuitive cognition moves have been discovered piece-meal, are often contradictory, and lack conceptual coherence.

The current point of departure for the empirical study of intuitive cognition within the general framework of judgment and decision research has also emphasized analytical models (e.g., Bayes' Theorem). In what may become a landmark review, Slovic, Fischhoff and Lichtenstein (1977) emphasized the trend in research that focuses on the inadequacies of intuitive cognition in relation to what such models of analytical cognition require. In addition, their review also documented the results of the theoretical open-endedness of current conceptions of intuition that take analytical models for their point of departure; the principal result being a variety of post hoc explanations and descriptions of departures from the analytical model; new experiments that include new conditions provide a new set of explanations. Slovic, Fischhoff, and Lichtenstein emphasize the diffuse nature of the results they review by quoting Krantz, Atkinson, Luce and Suppes (1974) as follows: "There is no lack of technically excellent papers in this area but they give no sense of any real cumulation of knowledge."

Despite the lack of conceptual analysis of the concept of intuition in judgment and decision research, the review by Slovic, Fischhoff and Lichtenstein (1977) makes it clear that two sharply different views of intuition exist, and that there is an important difference between them that motivates and guides current research.

Positive and negative views of intuitive cognition. Wescott's definition of intuition is definitely positive. Obviously it is a great advantage to be able to "arrive at plausible but tentative formulations (i.e., answers) without going through the analytical steps by which such formulations would be found to be valid or invalid conclusions" (p. 39). Surely it would be desirable to achieve plausible answers by "leaping over" the analytical steps necessary to produce and thus to justify them. Even the definition provided in Webster's Third International Dictionary is positive, thus: "Coming to direct knowledge or certainty without reasoning or inferring; immediate cognizance or conviction without reasoning."

Simon, in an article co-authored with Larkin, McDermott and D. Simon (1980), also takes the positive view. Expert performance in solving physics problems is identified with the use of intuition, thus:

> So we "explain" superior problem-solving skill by calling it "talent," "intuition," "judgment," and "imagination." . . . A person with good physical intuition can often solve difficult problems rapidly and without much conscious deliberation about a plan of attack. . . . But admitting the reality of physical intuition is simply the prelude to demanding an explanation for it. How does it operate, and how can it be acquired? (p. 1335)

And although the adjective "physical" precedes "intuition," it is doubtful that any restriction is intended, for they indicate that "expertness [intuition] probably has much the same foundations wherever encountered" (p. 1336).

In the positive view, intuition is hailed as an unmitigated cognitive asset; it indicates that enormous benefits may be provided by unconscious "leaps" to new discoveries, and the enormous benefits have often been cited in the history of mathematics, science, the arts and humanities. Seldom, if ever, does the positive view of intuition admit that there might be flaws in this process, or mention the possibility of costs of error; seldom does the positive view acknowledge that there might be negative aspects of intuition that are intrinsic to it. Not unexpectedly, the intuitive mode of cognition has generally been advocated by what the historian of ideas calls the "counter-enlightenment" of the 18th Century in which the scientific, rational approach to human affairs in general was denigrated as inappropriate, false and misleading.

In sharp contrast, it is generally the scientific, rational approach that has held the negative view of intuition, and it is this approach that has produced the research that indicates that intuitive cognition is inherently flawed. This is the view that is described so well in the Slovic et al. (1977) review, and is also neatly epitomized by the title of Ross's 1977 article: "The intuitive psychologist and his shortcomings: Distortions in the attribution process," and made the central theme in Nisbett and Ross's "Human inference: strategies and shortcomings of social judgment" (1980). In the negative view, the cognitive process that "arrives at plausible but tentative formulations without going through the analytical steps" is usually (if not always) not only wrong but misleadingly convincing. No one can read through the judgment and decision literature of the 60's and 70's without drawing the conclusion that intuition is a hazard, that it is a process that cannot be trusted, not only because it is inherently flawed by "biases," but because the person who resorts to it is innocently overconfident when employing it (Slovic et al., 1977). This point of view reached its culmination in Slovic's (1976) startling announcement that "Man may be an intellectual cripple." And, Slovic might have added, research shows that human beings are blissfully ignorant of their cognitive "biases," "shortcomings," "distortions," and generally "crippled" cognitive ability. A similar negative view is expressed by Kahneman and Tversky (1979), upon whose work Nisbett and Ross base their book, when they reply to Cohen's (1979) critique by saying:

> In conclusion, we can only invite the reader to look at the data presented in our papers and to judge whether the observed insensitivity to sample size, prior probability and reliability of evidence should be viewed as mistakes, which many of us are prone to make but would wish to correct, or as opinions which should be hold with pride and confidence. (1979, pp. 410-411)

In short, the positive view observes and celebrates successes, while failures are ignored or forgotten; the negative view observes (and, one suspects, also celebrates) failures; accounts of successful intuition are conspicuously absent from the research that endorses the negative view.

Despite their sharp differences, both positive and negative views share a common point of departure, namely, the analytical model; that is, the positive view praises, the negative view denigrates, the ability of intuitive cognition to reach conclusions that an analytical model would provide. But the heavy dependence on the analytical model as a point of departure for the study of cognition is not an absolute necessity; it was, in fact, rejected by two major theorists in psychology, Brunswik and Heider, and we now turn to their comprehensive view of cognition, for it will provide the basis for the present approach.

Brunswik and Heider on the merits of quasi-rationality and common sense. Brunswik and Heider provide two major exceptions to the use of analytical models, that is, rationalism, as a single reference point for the study of cognition; both theorize about the entire range of cognitive activity; that means that the intuitive aspects of cognition are to be identified and described in theoretical terms as well as the analytical aspects; each is to be seen in relation to the other. The principal difference between the two theorists is that Brunswik emphasized and enriched our conception of the environmental or task conditions that lead to different modes of cognition, whereas Heider emphasized and enriched our conception of the cognitive conditions that lead to different types of behavior. In order to see how the entire range of cognition is addressed by Brunswik, I provide his most explicit treatment of the differences between intuitive and analytical cognition, which is presented in terms of the distinction between thinking and perception, as follows:

The entire pattern of the reasoning [in contrast to perception] . . . resembles the switching of trains at a multiple junction, with each of the possible courses being well organized and of machine-like precision yet leading to drastically different destinations only one of which is acceptable in the light of the cognitive goal. This pattern is illustrative of the dangers inherent in explicit logical operations. The relative ease of switching off at any one of a series of choice points in a basically linear, unidimensional, all-or-none series of relays is at least in part the result of the precise formulation, yet relatively small number of basic cues, involved in most typical reasoning tasks. The combination of channeled mediation, on the one hand, with precision or else grotesquely scattered error in the results, on the other, may well be symptomatic of what appears to be the pure case of explicit intellectual fact-finding.

On the other hand, as we have seen, intuitive perception must simultaneously integrate many different avenues of approach, or cues. . . . [It] must remain based on insufficient evidence, that is, on criteria none of which is foolproof or fully ecologically 'valid.' . . . It is the insufficiency of single cues which must be seen as responsible for the establishment in perception of 'cue-family-hierarchies' (the phrase coined in analogy to Hull's 'habit-family-hierarchy,' see Brunswik, 1952, p.

19). . . .

A further feature, often noted by introspectionists in search of a distinction between intuitive perception and thinking, is the flash-like speed of perceptual responses. It is a biologically very valuable feature, especially where life is constantly threatened by sudden danger or where chances of success depend on quick action. The almost instantaneous promptness of perception could hardly be achieved without the stereotype and superficiality in the utilization of cues which we have noted and which makes for a certain intrinsic "stupidity" of the perceptual apparatus (see Brunswik, 1934, pp. 119 f., 128, 223 ff.).

The various rivalries and compromises that characterize these dynamics of check and balance in perception must be seen as chiefly responsible for the above noted relative infrequency of precision in perception. On the other hand, the organic multiplicity of factors entering the process constitutes an effective safeguard against drastic error in perception. . . . the "stupidity" of perception thus is by no means to be construed to mean maladaptiveness; as we all know, life has survived on relative stupidity from time immemorial, and if threatened in its existence it is so by malfunctioning of the intellect rather than by malfunctioning of perception.

Considering all the pros and cons of achievement, the balance sheet of perception versus thinking may thus seem seriously upset against thinking, unquestioned favorite of a culture of rational enlightenment as the latter has been. From the point of view of strategy, perception would likewise appear to have gained in stature by our realization of its inherent "vicarious functioning." So long as we accept, with Hunter (1928) and Tolman (1932), vicariousness as the foremost objective criterion of behavioral purposiveness, perception must appear as the more truly behavior-like function when compared with deductive reasoning with its machine-like, precariously one-tracked, tight-rope modes of procedure. The constantly looming catastrophes of the intellect would be found more often to develop into catastrophes of action were it not for the mellowing effect of the darker, more feeling-like and thus more dramatically convincing primordial layers of cognitive adjustment. (1956, pp. 91-93)

Thus, we see that Brunswik provided conceptual descriptions of <u>both</u> types of cognitive activity; the intuitive form of cognition was described as well as the analytical form; most important, cognitive problems were not limited to those to which an analytical model can readily speak.

Heider's (1958) approach is similar; and although he does not differentiate as sharply as he might between intuition and common sense, he states his admiration for the value of common sense at the outset of his book, thus:

the study of common-sense psychology may be of value because of the truths it contains, notwithstanding the fact that many psychologists have mistrusted and even looked down on such unschooled understanding of human behavior. For these psychologists, what one knows intuitively, what one understands through untrained reflection, offers little--at best a superficial and chaotic view of things, at worst a distortion [c.f. Nisbett and Ross, 1980] of psychological events. They point, for example, to the many contradictions that are to be found in this body of material, such as antithetical proverbs or contradictions in a person's interpretation of even simple events. But can a scientist accept such contradictions as proof of the worthlessness of common-sense psychology? If we were to do so, then we would also have to reject the scientific approach, for history is fraught with contradictions among theories, and even among experimental findings. We would have to concur with Skinner who actually draws this conclusion in regard to theory-making in the psychology of learning (Skinner, 1950).

This book defends the opposite point of view, namely, that scientific psychology has a good deal to learn from common-sense psychology. In interpersonal relations, perhaps more than in any other field of knowledge, fruitful concepts and hunches for hypothesis lie dormant and unformulated in what we know intuitively. . . . Whitehead, writing as a philosopher, mathematician, and educator, has still further elevated the status of common-sense ideas by according to them an essential place in all sciences. He has stated:

> whole apparatus of common sense thought. That is the datum from which it starts, and to which it must recur. . . . You may polish up common sense, you may contradict it in detail, you may suprise it. But ultimately your whole task is to satisfy it. (Whitehead, 1929, p. 110.)

Oppenheimer, the physicist, has also stated this view with equal firmness:

> adaptations of common sense. [Italics mine] (Oppenheimer, 1956, p. 128) . . .

Actually, all psychologists use common-sense ideas in their scientific thinking; but they usually do so without analyzing them and making them explicit. (1958, pp. 5-6)

This strongly positive view of common sense by Heider, the psychologist who introduced attribution theory, is in sharp (and curious) contrast to the negative view expressed by current advocates of attribution theory (e.g., Nisbett and Ross, forthcoming 1981) who have emphasized the negative characteristics of cognition, namely, its "distortions" and "shortcomings," in line with the general trend noted by Slovic, Fischhoff and Lichtenstein in their 1977 review mentioned above and confirmed by Einhorn and Hogarth in their 1980 review.

I cite at length the views of Brunswik and Heider because they can provide the basic theoretical materials upon which a broad, comprehensive theory of social judgment and decision making (as well as problem-solving) can be constructed. In the next section, the nature of such a comprehensive theory is described.

A comprehensive view of cognition. In the comprehensive view advocated here the (generally neglected) intuitive pole of cognition is as strongly anchored in theory and task conditions as the (generally well-treated) analytical pole of cognition; most important, the full range of task conditions and cognitive activities between the poles of the cognitive continuum is considered as well. Intuition, therefore, is not described as a cognitive process that "omits steps," or that entails a "distortion" or "shortcoming," or employs a "heuristic" that provides an incorrect answer to problems for which current analytical tools would have provided a correct answer, had they been used; it is not defined in terms of what it is not. Correct as these descriptions of intuitive cognition may be (a matter we engage in detail below), they can apply only to those restricted cases to which a specific analytical model may justifiably be employed, and for which, therefore, omitted steps can be identified and described a priori.

Moreover, the comprehensive view, on the other hand, considers the "middle ground" of the cognitive continuum, rather than simply the departure from rationality in the form of an analytical model. And it does so because the value of that "middle ground" (Brunswik's quasi-rationality, Heider's common sense) can be justified with regard to its functional utility in those environmental circumstances in which the use of analytical models (a) cannot be unconditionally employed, i.e., a single specific model cannot be justifiably employed by either researcher or subject sheerly on analytical grounds, and (b) analytical models are not available for employment by the researcher. In neither of these cases may an analytical model be used as a standard against which to evaluate the subject's cognitive activity. Each is discussed in turn.

Analytical models available but not unconditionally employable by researcher or subject. Circumstances in which analytical models are available but cannot be justifiably employed include those in which there is no single, concensus-based criterion which will permit the investigator to choose among competing analytical models. This topic receives the following comment from Einhorn and Hogarth (in press) in their chapter in the Annual Review of Psychology, a comment which marks the advance in sophistication in the field between 1977 and 1981.

Task vs Optimal Model of Task

> We begin by offering a definition of optimality; viz., decisions or judgments that maximize or minimize some explicit and measurable criterion (e.g., profits, errors, time) conditional on certain environmental assumptions and a specified time horizon. The importance of this definition is that it stresses the conditional nature of optimality. For example, Simon (1979) points out that because of the complexity of the environment, one has but two alternatives: either to build optimal models by making simplifying environmental assumptions; or to build heuristic models that maintain greater environmental realism (also see Wimsatt,

1980). Unfortunately, the conditional nature of optimal models has not been appreciated and too few researchers have considered their limitations. For instance, it has been found that people are insufficiently regressive in their predictions (Kahneman & Tversky, 1973). While this is no doubt true in stable situations, extreme predictions are not suboptimal in non-stationary processes. In fact, given a changing process, regressive predictions are suboptimal. The problem is that extreme responses can occur at random <u>or</u> they can signal changes in the underlying process. For example, if you think that Chrysler's recent large losses are being generated by a stable process you should predict that profits will regress up to their mean level. However, if you take the large losses as indicating a deteriorating quality of management and worsening market conditions, you should be predicting even more extreme losses. Therefore, the optimal prediction is conditional on which hypothesis you hold.

The above is not an isolated case. For example, Lopes (1980) points out that the conclusion that people have erroneous conceptions of randomness (e.g., Slovic, Kunreuther & White, 1974), rests on the assumption that well-defined criteria of randomness exist. She convincingly demonstrates that this is not the case. Or consider the work on probability revision within the Bayesian framework (e.g., Slovic & Lichtenstein, 1971). Much of this work makes assumptions (conditional independence, perfectly reliable data, well defined sample spaces), that may not characterize the natural environment. Moreover, alternative normative models for making probabilistic inferences have been developed based on assumptions different from those held by Bayesians (Schaeffer, 1976; Cohen, 1977; also see Schum, 1979, for a discussion of Cohen). In fact, Cohen's model rests on a radically different system that obeys rules quite different from the standard probability calculus. Competing normative models complicate the definition of what is a "bias" in probability judgment and has already led to one debate (Cohen, 1979; Kahneman & Tversky, 1979b). Such debate is useful if for no other reason than it focuses attention on the conditionality of normative models. To consider human judgment as suboptimal without discussion of the limitations of optimal models is naive.

The difference between Slovic et al. (1977) and Einhorn and Hogarth (in press) is epitomized in the final sentence of the above quotation; there are no remarks about naivete in Slovic et al., (1977) with regard to the use of analytical models. The difference lies in the newly-found observation that circumstances exist in which <u>several</u> analytical models may be available; the choice of which to employ as a standard will then be the result of quasi-rational cognitive activity.

Simon (1979) makes the same point with regard to the quasi-rational choice of analytical models (i.e., theories) in economics when he says: "Thus economists who are zealous in insisting that economic actors maximize turn around and become satisficers when the evaluation of their own theories is concerned," (p. 495). Simon's observation fits with that of Whitehead quoted by Heider (p. 6, 1958): "Science is rooted in what I have just called the whole apparatus of common sense thought. That is the datum from which it starts and to which it must recur . . . . You may polish up common sense, you may contradict it in detail, you may surprise it. But ultimately your whole task is to satisfy it" (Whitehead, 1929, p. 110). Simon's and Whitehead's remarks are borne out in an unexpected, and, one must say, ironical, way by the response made by Kahneman & Tversky (1979) to Cohen (1979) indicated above in which these authors, in the same sentence in which they denigrate the "mistakes" of human judgment, invite their readers to "judge" the issue between Cohen and themselves, and thus to become subject to the very "mistakes" which Kahneman and Tversky warn against. In short, if there is more than one analytical model to choose from, economic theorists, psychological researchers and the man in the street, resort to their quasi-rational judgment in their effort to choose among them, and no single analytical model can be used to evaluate these judgments. This conclusion was not obvious in 1977.

The point is not to deny that the use of a singular analytical model can be fully justified by the researcher on well-specified occasions and thus used to evaluate the cognitive activity that produced the judgments and choices of subjects. Rather, the application of analytical models as evaluative devices must carefully delineate the conditions on those occasions in which such models are employed, a delineation that has not always occurred, as Einhorn & Hogarth (in press) note. Most important, on those occasions in which the researcher identifies or employs a task that is not fully susceptible to analytical cognition, the behavior of the subject should be evaluated in light of that information. In this way, Simon's economists who prefer (analytical) maximizing theories, but exercise quasi-rational cognitive activity in their choices among such theories, are simply coping with a less-than-fully-analytical task (for which no singular analytical choice model is available) in a less-than-fully-analytical manner. In Whitehead's words they are attempting to "satisfy" common sense; in Simon's words, they "satisfice"; in our terms, they are quasi-rational; in any case, they _may be behaving appropriately_ in the absence of a singular analytical model, rather than stupidly deceiving themselves (an argument to be developed in detail below in relation to the match between modes of cognition and task characteristics).

Analytical models not available for employment by researchers or subject. In many circumstances analytical models cannot be employed because none exist; in other circumstances, only partially analytical models are available. More generally, it will be useful to consider a continuum along which models of environments can be ordered from "hard" to "soft." At one end, the terrestrial macro-physical environment (or at least large segments of it) can be modeled by a "hard," singular (e.g., Newtonian) model. Such analytical models are hard because they are fully explicable by measurable parameters, long theoretically and empirically justified. At the other end of the continuum are those personal-social environments for which only partially defensible models exist; that is, those environments that are partially understood, often called unstructured or "ill structured" (Simon's phrase) tasks. These environments contain some "hard" parameters that are measurable and whose relations are empirically verifiable, but also include some "soft" parameters for which non-retraceable judgments must be substituted for retraceable measurements. Analysis of the cognitive activity of subjects who must exercise their judgment in these circumstances is at least as important as the analysis of their cognitive activity in the case of those circumstances at the polar extreme at which analytical models (such as Bayes' Theorem) are readily available. Of course, some environmental models are completely "soft".

The comprehensive view of cognition thus takes into account not only those judgment and decision tasks for which analytical models may be employed to evaluate the rationality or logical defensibility of cognition but those tasks for which only quasi-rationality may be justified. We turn now to a description of this concept.

Quasi-rationality. The concept of quasi-rationality arose from Brunswik's description of perception as a "compromise" between the proximal (retinal) pole, and the distal pole, the object in the environment. Quasi-rationality is the term to be applied to the _compromise_ between the poles of cognition--intuition and analysis. And just as conditions of illumination may pull the perception of an object _toward_ the pole of retinal size and thus _away from_ object size (or the reverse), so may task conditions pull cognitive activity toward intuition and away from analysis (or vice versa). Thus, an either-or position with regard to intuition and analysis is avoided. As Brunswik put it, "In this light perception and the different varieties of thinking begin to reveal themselves as but different forms of imperfect reasoning, each with its own particular brands of virtues and 'stupidity,' if the term be permitted . . . . "(Hammond, 1966, p. 491).

Brunswik linked the concept of quasi-rationality directly to research in judgment in his 1952 monograph , thus:

> In an attempt at rational reconstruction of the ways of the quasi-rational, with its reliance on vicarious cues each of which is of limited validity, one may best refer to a remark of Thorndike [1918] comparing the impressionistic or intuitive judge of men to a device capable of performing what is known to statisticians as multiple correlation. (p. 24)

Thus Brunswik introduces the theoretical basis for the use of multiple regression as a mathematical model for quasi-rational cognition. (Note the task conditions; numerous contemporaneously displayed, intersubstitutable cues of limited validity.) Brunswik continues by contrasting quasi-rationality with rationality: "By contrast, man-made gun or tank-stabilizers and the related 'thinking machines' may . . . perform in a practically foolproof manner. This is due to the fact that they can usually be built with a concentration on a few cues of maximal trustworthiness and thus dispense with the services of cues of limited validity."

Heider placed a similar emphasis on vicarious mediation in his early and highly significant paper "Ding und Medium" in 1926, in which the term "manifold of offshoots" or "event patterns" is used to refer to mediation (in 1958) and he notes (1958, p. 35) the vicarious nature of such mediation. I also argued at that time that "Vicarious functioning . . . lies at the heart of the private, quasi-rational nature of the clinical decision" (Hammond, 1955, p. 258). And, it might have been said, vicarious functioning lies at the heart of the private, quasi-rational decisions that occur so frequently in social circumstances.

Other task characteristics aside from dependence on "cues of limited validity" that move cognition from its analytical form toward quasi-rationality include the following: (a) a large number of cues to be considered simultaneously rather than sequentially, (b) a short time in which to make a judgment or reach a solution, (c) the necessity of defining, labelling and measuring task dimensions oneself, and, most important, (d) the absence of a familiar, readily applied, organizing principle; others are listed and discussed in detail below.

These task conditions lead to quasi-rational cognition that is characterized by less-than-perfect cognitive control, unconscious, rapid data processing in which raw data or events are stored in memory and in which pictorial imagery appears, as well as other cognitive conditions listed below. The behavior of subjects in which quasi-rational cognition is induced will exhibit inconsistency of both a temporal and logical variety, will be less aware of, and thus be less able to, retrace their judgment processes, will exhibit a brief response time, and exhibit event memory rather than memory for principles. Further details are provided below in relation to Premise 3, in which a tighter and systematic link between task properties, cognitive properties and behavior is presented. Before establishing these links, however, it will be in the interests of unification to examine the concept of "bounded rationality," introduced by Simon (1957), because of the similarity between quasi-rationality and bounded rationality, and also because of Newell and Simon's (1972) acknowledgment of Brunswik's influence on their work.

There is some uncertainty in this writer's mind about the generality that Simon intends to impute to bounded rationality. For while it has a large role in many of his articles dealing with economic theory (see, e.g., his Nobel acceptance speech, 1979, p. 497 ff.), in which he notes that bounded rationality is largely brought about by the "limits of man's ability to comprehend and compute in the face of complexity and uncertainty" (p. 501), it is not mentioned in his "Sciences of the Artificial" (1969) nor in the recent article with Larkin et al. (1980) regarding "physical intuition". Indeed, physical intuition appears to be highly rational and anything but "bounded"; rather, its <u>rational</u> character is emphasized. For example: "large numbers of patterns serve as an index to guide the expert in a fraction of a second to relevant parts of an information store. This knowledge includes sets of rich schemata that can guide a problem's interpretation and solution and add crucial pieces of information. This capacity to use pattern-indexed schemata is probably a large part of what we call physical intuition" (p. 1342).

The separation of the concept of bounded rationality from the work in problem-solving is further illustrated in Simon's recent article in Science (1980) in which he summarizes progress in the social sciences and selects three areas for discussion because of the "intellectual excitement they engender" (p. 73). They are "evolutionary theory . . . , the theory of rational choice . . . , [and] . . . the newly christened discipline (or interdiscipline) of cognitive science" (p. 73). The clear separation of the topic of "rational choice" from that of "cognitive science" is, from the point of view of the present writer, curious, if not peculiar, but it does offer an explanation for the separation of "bounded rationality" from "list structure". Apparently Simon believes that these concepts apply to two (entirely?) different topics, or even disciplines. Bounded rationality does appear to be part of a theory of problem-solving as well as part of a theory of choice, for although the clear impression is given in the article with Larkin et al. (1980) that bounded rationality is not applicable to the cognitive activity of <u>experts</u>, it seems that it is applicable to the cognitive behavior of <u>novices</u>. If this interpretation is correct, then we can conclude that in all cases in which the problem-solver is a novice, "bounded rationality" and "satisficing" will account for the difference between their problem-solving behavior and that of the expert. Perhaps this can be taken to mean that novices, but not experts, will exhibit the properties of quasi-rational cognition indicated above. Even so, both positive and negative views of bounded rationality may be found.

Positive and negative views of bounded rationality. Bounded rationality is apparently directed toward explaining the behavior of persons in situations much less subject to detailed description than physics problems (which may perhaps explain its absence from the two above-mentioned publications). Thus, for example, March (1978, p. 591) in a major paper on this topic indicates that

> Ideas of _limited rationality_ emphasize the extent to which individuals and groups simplify a decision problem because of the difficulties of anticipating or considering all alternatives and all information . . . . They introduce, as reasonable responses such things as step-functions, tastes, simple search rules [cf. Thorngate, 1980] working backward, organizational slack, incrementation, and muddling through, uncertainty avoidance.

Further, bounded rationality is more apt to be found in connection with, "Limitations of memory organization and retrieval and information capacity" (p. 598).

March (1978) develops the broad implications of bounded rationality in a manner quite different from Simon, and in doing so, raises the same question regarding the positive and negative value of quasi-rational cognition that was described earlier in connection with intuition. Indeed, in this article March begins to look askance at _rationality_. For example, after describing a variety of types of rationality other than "calculated rationality" March observes that "If behavior that apparently deviates from standard procedures of calculated rationality can be shown to be intelligent, then it can plausibly be argued that models of calculated rationality are deficient not only as descriptors of human behavior but also as guides to intelligent choice" (p. 573). This comment elevates the concept of bounded rationality to something <u>better</u> than "calculated rationality." Further,

> One of Simon's contributions to the theory of choice was his challenge of the self-evident proposition that choice behavior necessarily would be improved if it were made more like the normative model of rational choice. By asserting that certain limits on rationality stemmed from properties of the human organism, he emphasized the possibility that actual human choice behavior was more intelligent than it appeared (p. 574)

(cf. the negative view of intuition described above). Moreover, "goal ambiguity, like limited rationality, is not necessarily a fault in human choice to be corrected but often a form of intelligent choice to be refined by the techology of choice rather than ignored by it" (p. 598).

These remarks, and many similar ones in the same article, point in the same direction as those made by Brunswik and Heider (and others) regarding the positive value of quasi-rational cognition; they suggest that elements other than "calculated rationality" may serve to enhance "intelligent", that is, adaptive, successful behavior; they are consistent with the positive view of the forms of cognition that are not analytical, or "calculated". But if quasi-rationality needs to be marked off from calculated rationality, it must also be separated from <u>irrationality</u>. Among his earliest (1957) discussions of bounded rationality, Simon took pains to do just that:

> <u>Bounded Rationality Contrasted with "Irrationality."</u> It is important to distinguish between the principle of bounded rationality . . . and the contemporary emphasis in social psychology upon the affective, nonrational factors in human behavior. Fashion in the scientific explanation of man's behavior oscillates between theories that assign supremacy to his reason and those that give predominance to his passions. The synchronized push that Freud and Pareto gave to this pendulum has, for the past generation, kept it far over on the side of passion. . . . One of the difficulties--perhaps the most serious--in incorporating cognitive processes in the theory of social behavior is that we have not had a good description of those processes . . . the received theory of rational choice is a theory that almost completely ignores the limits of humans as mechanisms for computation and choice--what we have called the principle of bounded rationality. (p. 200)

The parallel between Simon's (1957) views with Brunswik's (1952) regarding the "rational reconstruction of the ways of the quasi-rational" can be seen in the following paragraph from Simon (1957, p. 200), in which it also important to note that Simon hints that we may someday change our views about what is "rational":

> The central task of these essays, then, is not to substitute the irrational for the rational in the

> explanation of human behavior but to reconstruct the theory of the rational, making of it a theory that can, with some pretense of realism, be applied to the behavior of human beings. When we have made some progress with this reconstruction, I believe that the return swing of the pendulum will begin, that we will begin to interpret as rational and reasonable many facets of human behavior that we now explain in terms of affect. It is this belief that leads me to characterize behavior in organizations as "intendedly rational."

Negative views of quasi-rational activity are apt to be found in the remarks of those who hold negative views of intuition (see above), but it is difficult to be certain about the limits of these views. For those researchers who hold negative views about intuition generally qualify these views by remarks that indicate that intuitive cognition is "useful" on certain occasions. Specific denotations of the circumstances under which "distortions," "shortcomings," and "biases" will or will not be employed have not been developed as clearly as one might have hoped, however. Be that as it may, among those who have taken a negative view of intuition, as, for example, Nisbett and Ross (1980) have, none has offered the hypothesis expressed by March, that bounded rationality may lead to <u>more</u> "intelligent" decisions than "calculated rationality". None has offered the suggestion that certain heuristics should be used in place of calculated rationality when the latter can be used. All of which raises the question of the congruence between the various characteristics of cognition and the characteristics of cognitive tasks.

Congruence between characteristics of cognition and characteristics of cognitive tasks. Current theory and research focuses on one form of mismatch between modes of cognition and types of cognitive tasks. The type of mismatch that is illustrated by those emphasizing the negative view of cognition describes the application of quasi-rationality (or bounded rationality) to problems that are susceptible to calculated rationality and emphasizes the errors ("shortcomings and distortions") that follow from this type of mismatch. This is an important case, to be sure, but it must not be allowed to be mistaken for, or to obscure, the occurrence of other mismatches namely, the application of analysis or "calculated rationality" where, as March (1978) points out, other aspects of rationality might be applied. Nor are the results of the currently emphasized mismatch to be gratuitously generalized to other mismatches, a risk that is inherent in both the positive and the negative view, in contrast to the comprehensive view of cognition.

Dangerous as it may be for human beings to fail to employ analytical cognition when it is appropriate and needed, the danger from the opposite mismatch should not be overlooked. Indeed (as noted above), Brunswik pointed out that the greater threat may well come from the mismatch between task and mode of cognition in which analytical cognition is unrestrained by intuition, thus: "The constantly looming catastrophes of the intellect would be found more often to develop into catastrophes of action were it not for the darker, more feeling-like, and thus more dramatically convincing primordial layers of cognitive adjustment" (1956, p. 93). Examples of the mismatch that lead to "catastrophes of the intellect" are easy to find as the analytical methods of science and technology come to be applied to the confused and entangled social and environmental problems that demand moral, as well as technical, judgments. The analytical approach attributed (fairly or not) to the U.S. policy makers during the Viet Nam war has come to be the major symbol of this type of mismatch. (See Hampshire for a general treatment of the misapplication of utilitarianism in "Public and Private Morality," 1978.)

Striking foresight regarding the dangers of the misapplication of analytical cognition is contained in the following sentence written by Brunswik in 1946. "The perils of entrusting decision making to linear single-cue systems in which the throwing of a switch threatens collapse are brought home more in earnest when we remember that certainty-geared interaction may go wrong not only as to deductive routines but also on the inductive leg of the inferential process" (Hammond, 1966, p. 490). March (1978) confirms this "peril" by referring to the "tales of horror that have become contemporary cliches of studies of rational analysis" (p. 588). (See also Lindblom and Cohen regarding "Usable Knowledge," 1979.)

In the light of these remarks, it may be useful to contrast polar views regarding cognition that have been expressed in the past. Hume's well-known admonition expresses the negative view of intuition: "If we take in our hand any volume . . . let us ask, Does it contain any abstract reasoning concerning number or volume? No. Does it contain any experimental reasoning concerning matter of fact and existence? No. Commit then to the flames, for it can contain nothing but sophistry and illusion." Blake's reaction boldly celebrates the positive view: "I come in the grandeur of inspiration to abolish ratiocination." But Pascal's comprehensive viewpoint is the one adopted here: "Two extravagances: To exclude Reason, to include only Reason."

In the comprehensive view, all forms of cognition make special contributions to adaptation and achievement, and every form of cognition carries its own risks and benefits; none is to be seen as the prototype, or normative model, for all others. This means that excessive zeal for the benefits of analytical cognition is to be avoided if an asymmetrical, and perhaps dangerous, view of cognition is to be avoided, just as the romantic vision of the counter-enlightenment is also to be treated with skepticism. The frequently occurring cognitive tasks of the middle range for which analytical models are useful and appropriate only in part, must be treated theoretically and empirically, as well as tasks for which an analytical model can be readily found. Indeed, it is the tasks of the middle range that should have the highest research priority, because they pose the cognitive problems of everyday life. Additionally, tasks that induce quasi-rationality are the tasks that confront policy makers; tasks for which a general outline, or theoretical framework, of an analytical model may be available from the laboratory, or computer, or pure theory, but for which the direct application of analytical models is inhibited, frustrated, or thwarted by the tangled, poorly understood task conditions outside the laboratory (in which social values are prominent) to which the analytical models must be applied, often on a grand scale.

Summary. Premise one is essential to a unifying theory because it presents cognition as a continuum, rather than a dichotomy. Premise Two pursues the idea of a continuum further by asserting that elements of both intuitive and analytical cognition are present in most cognitive activity, that is, in most judgments and decisions. Premise Two substitutes a comprehensive view of cognition for the positive and negative views of intuition and analysis that are currently held, and thus makes it possible to see work of various researchers as coping with different combinations of intuition and analysis, that is, quasi-rationality. What remains for us to accomplish, then, is to describe the variety of task conditions in detail, to discover the varieties of cognition induced by them, and eventually to discover the appropriate relation between task conditions and cognitive activity (cf. Brunswik, 1952; Simon, 1956).

Premise 3

The properties of cognitive tasks permit them to be ordered on a continuum with regard to their capacity to induce elements of intuitive and analytical cognition. Thus, an a priori relation is specified between the properties of cognitive tasks and the modes of cognition induced by them.

The source of this premise is Tolman and Brunswik's "Causal Texture of the Environment" (1935). One of the few articles to emphasize the complexity (thus "texture") of the task environment, its current influence can be seen in the remarks of Newell and Simon, who, in citing Tolman and Brunswik's work as the basis for theirs, say: "Just as a scissors cannot cut paper without two blades, a theory of thinking and problem solving cannot predict behavior unless it encompasses both an analysis of the structure of task environments and an examination of the limits of rational adaptation to task requirements" (1972, p. 55). Somewhat earlier Simon (1969) also observed that: "my general hypothesis [is] that in large part human goal directed behavior simply reflects the shape of the environment in which it takes place (p. 34).

Simon's emphasis on the importance of the structure of the environment in evoking or inducing various cognitive processes was most clearly stated, however, in his article entitled "Rational choice and the structure of the environment" (1956). Although neither Tolman nor Brunswik are referenced, the ideas expressed in this paper are wholly compatible with theirs. Thus, for example:

> Now if an organism is confronted with the problem of behaving approximately rationally, or adaptively, in a particular environment, the kinds of simplifications that are suitable may depend not only on the characteristics--sensory, neural and others--of the organism but <u>equally</u> [italics mine] upon the structure of the environment. Hence, we might hope to discover, by a careful examination of some of the fundamental structural characteristics of the environment, some further clues as to

> the nature of the approximating mechanisms used in decision making. (p. 130)

The parallel between this programmatic statement and the key statement made by Brunswik in 1955 (Brunswik, 1957) at the Colorado Symposium on Cognition is worth noting. According to Brunswik,

> Both organism and environment will have to be seen as systems, each with properties of its own . . . . Each has surface and depth, or overt and covert regions . . . . It follows that, much as psychology must be concerned with the texture of the organism or of its nervous properties and investigate them in depth, it must also be concerned with the texture of the environment. (1957, p. 5; see also Hammond, 1966)

Despite these programmatic goals that emphasize the structure of environmental tasks, far more attention has been given to intra-organismic systems than environmental task systems by all concerned. Rival theories of organismic systems of cognition proliferate, but theories of task structure lack sufficient form to achieve an identity, let alone competitiveness. Simon's theory of a "list structure" applies to organisms; where is the comparable concept to be applied to the structure of the environmental task? Tversky and Kahneman speak of heuristics that describe organismic cognitive activity; but their conception of the environment is exhausted by an analytical statistical model. Edwards (1971) has spoken of the need for a "taxonomy of tasks," but has offered no concepts with which environmental structure might be described. Neither Anderson nor the various attribution theorists mention the need for environmental theory.

The present author introduced the "Principle of Parallel Concepts" (Hammond, Stewart, Brehmer & Steinman, 1975) in an effort to provide a conceptual framework for describing task structure; but, of course, it is far from satisfactory. It merely argues that the same (i.e., parallel) concepts that are used to describe organismic cognitive systems can be used to describe the structure (and functioning) of environmental tasks. The argument is supported by empirical demonstration, but the range of tasks is too narrow. Moreover, there is no explanation of how the task structure is mediated by cognitive activity, as, for example, Kahneman and Tversky indicate that statistical information is mediated by cognitive heuristics that produce judgments.

Theories of task structure should, at a minimum, specify task properties that are linked to (unobservable) cognitive activities whose behavioral contingencies are predicted by task properties. That is the method that will be followed here: task properties will be described and linked to cognitive activities, which in turn will be linked to their behavioral consequences. And although I begin with a list of characteristics of task properties, the effort is not encyclopedic, but theoretical.

A theory of task structure. In what follows I make the attempt to provide (a) a full set of task properties that induce intuition and analysis (Table 1), (b) a full set of the properties of the cognitive activities to be termed intuitive and analytical (Table 2) and (c) a full set of the judgment and decision behaviors that are predicted to follow from the task properties and cognitive activities (indicated in Tables 1 and 2) in Table 3. Before discussing these tables, the reader should

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Tables 1, 2 and 3 here

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be reminded that Tables 1, 2, and 3 describe the poles of the cognitive continuum for the convenience of explication only, and that the principal assertion of the Cognitive Continuum Theory is that nearly all judgments and decisions are quasi-rational (including the choice of analytical theories) and thus require elements of both processes (a matter discussed in detail with regard to Premise 2 above). Thus, intuition will be described as completely as analysis; analytical cognition is not the only point of departure. In addition to explicating and specifying the properties of cognitive tasks, I predict the forms of cognition various task properties induce, and I try to explain why each task property in Table 1 induces the form of cognition it does.

But, as always in psychological theory, the matter of subjective and objective referents for these terms must be discussed.

Subjective and objective referents. An objective referent requires a series of observations in which inter-observer reliabilities approximate unity; as inter-observer reliability decreases, the referents for a term thus become more ambiguous and therefore subjective. Although all objectivity has inescapable observational referents, a retreat to pure phenomenology is neither necessary nor desirable for our purposes. When applied to task conditions the terms that define the poles of the cognitive continuum should be objective (in the above sense). Thus, the terms that are used to define task properties should be defined independently of the observations of any individual subject, insofar as possible.

Adherence to a strict, simplistic objectivity of this sort will not, however, be possible or desirable in research on judgment and decision making--in the present state of the art, at least. To take an example (which, although obvious, has never been discussed in any detail in the judgment and decision literature), consider the matter of defining the number of cues in a judgment task. A task that objectively presents a large number (5+) of cues to a person who is a novice with regard to the task, may present only two cues to an expert, for a person who brings a competent organizing principle to the task may thereby reduce a large number of cues to a few by "chunking" or organizing them (cf. Simon, 1969, pp. 42-47). Reliance solely on the objective description of task properties would in this case lead the researcher to anticipate incorrectly that an intuitive mode of cognition would be induced in both novice and expert. Contrariwise, experts may be (and have been) reduced to novices when they are not provided with the information they require in order to function as experts (i.e., in order to bring the organizing principle they possess to bear on the task).

This conclusion does not mean, however, that researchers must resort to a posteriori or ad hoc definitions. A priori definitions and denotations of organizing principles and other cognitive properties can be obtained (or put in place) prior to the experiment, although such a priori specifications are seldom made. An example of research in which cognitive properties are described and put in place prior to the test conditions can be found in the research on cognitive conflict (see e.g., Hammond, Brehmer, Stewart & Steinmann, 1975) and on the effects of psychotherapeutic drugs on judgment (Gillis, 1975, 1980) and a series of studies by Brehmer (1980). More generally, research as far back as that of Krechevsky's in the 1930s was conducted precisely to show that the tabula rasa assumption does not hold for rats; that is, even rats introduced into a maze have an a priori hierarchical order of organizing principles, a Kantian finding that ethologists and behavioral geneticists have since confirmed for a wide variety of organisms and one that Brehmer (1974) has apparently established for human beings regarding the order of their use of function forms. (For an interesting parallel with the hierarchical cue utilization of homing pigeons and bees, see Gould, 1980.)

In short, theory and research in judgment and decision making must include reference to the a priori cognitive content and process that subjects bring to the research task; and this material must be included in the definition of task properties for each subject (cf. Einhorn and Hogarth, in press, on "task representation"). Definitions of task situations should, therefore, include objective descriptions of both task properties and cognitive properties brought to the task by the subject. (These descriptions should include, if possible, the presumptions subjects may have regarding the aims of the researcher.)

I turn now to the polar terms used to explicate the meaning of intuition, quasi-rationality, and analysis within the framework of Cognitive Continuum Theory. They are grouped into three main categories: (a) complexity of task structure, (b) ambiguity of task content, and (c) form of task presentation. Details are presented in Tables 1, 2 and 3; explication and explanation follow.

Complexity of task structure. The complexity of the space that separates the palpable, proximal cues from the impalpable, distal variable to be inferred can be described in several ways, but distance in the separation is critical. Distal-proximal separation is shallow when causal texture is at a minimum (as, for example, was this poker chip drawn from this bag or that one?). In this case the task does not offer several hierarchies of interdependent causal variables, or an intricate causal network through which the subject must work. Distal-proximal separation is deep, on the other hand, when the subject must consider a tangled network of interdependent, partial causes and effects and cannot subject them to piecemeal, orthogonal disentanglement. (Artifactual tasks are often constructed to shorten the deep distal-proximal separation that naturalistic tasks often present.) Therefore, when the task offers a large amount of depth, the variation in the formal properties of tasks determines their complexity. That is, the formal properties of the region between the readily observable (proximal) data and the yet-to-be observed (distal) data to be inferred determines the complexity of the causal texture of the task. The parameters of this region that can be, and often are, manipulated by the researcher include, in the single-system (i.e., no criterion available) case, (a) the texture of the judgments required, (b) the number of cues presented for each judgment, (c) the degree of vicarious mediation (intra-ecological correlation) among cues, and (d) cue distribution characteristics; in the double-system (logical or empirical criterion available) case, (e) the shape of the function forms between cue and distal variable, (f) variation in the ecological validities of the cues, and (g) the organizational principle linking the cues to the distal variable. Each is discussed in turn.

1. The texture of the judgment scale. "Texture" refers to (a) a horizontal component, namely, the number of alternatives a person must consider, and (b) a vertical component (the number of steps to solution). Wide variations in the texture of judgment scales have been used in judgment and decision research questions (e.g., cf. the dichotomous judgment scales typically used in the research by Tversky and Kahneman (1974) with the continuous scales typically used by Anderson (1979). Wide variations also occur with regard to steps to a solution (cf. work in the revision of probabilities on the basis of new information vs. multiple cue probability learning.)

2. The number of cues presented for each judgment. Cues are generally identified by the researcher as palpable (proximal) potential sources of information about an impalpable (distal) variable. Cues may be organized into patterns that also serve as cues; that is, hierarchies of cue organization may be created by the researcher or subject. Thus, for example, individual cues (e.g., chess pieces) may be organized into subjective patterns that may be

used as a basis for the inference of an impalpable environmental state (e.g., "this way lies victory"). As indicated above in the discussion of subjective and objective referents, such potential organizations of cues can, and should, be specified a priori by the researcher, and the intra- and inter-subjective reliability of such organizations assessed. When organizations of cues are defined post hoc, they must, of course, be cross-validated. The same is true with regard to language; individual words may serve as cues, and organizations of words (sentences, paragraphs) may also serve as cues. Such "chunking" of cues depends on the presence of an organizing principle (about which more below).

When the intra- and/or inter-subjective reliability of judgments regarding the cue falls below some functionally-determined criterion (e.g., .95), it is called an "ambiguous cue." In general, the <u>ambiguity</u> of a cue can be described or measured in terms of its "ecological reliability" (in contrast to <u>ecological validity</u>; cf. Brunswik, 1956, pp. 30, 35, 37, 38, who provides the only discussion of this matter, so far as I know). Cues have varied in number from at least 27 (Doherty, 1980) to two.

If many cues are presented, they may be displayed contemporaneously or sequentially. If several cues are displayed contemporaneously, the subject typically is then asked for his/her judgment, and then a new set of cue values that requires a judgment is displayed. Thus, for example, a subject may make a judgment about another person's character from a photograph that (contemporaneously) displays all the physiognomic cues present in a face. After that judgment is made, a new photograph is presented and a judgment for the second face is made (without explicit reference to the first). Although the values of the several cues may change (e.g., more or fewer wrinkles in the faces) the number of potential cues does not change over trials.

In contrast, tasks may provide "part" displays; that is, they provide the subject with part of the information regarding the task on one trial and new information on new dimensions or cues on subsequent trials. Additionally, some tasks provide choice points for judgments as the new cues (or new cue values) are encountered. One choice may be to "move back," that is, to revise a previous choice; "roving" back and forth across previous and potential future choices is sometimes permitted.

3. Vicarious mediation, (intersubstitutability, redundancy) vs. univocal cue presentation. Vicarious mediation refers to the manner in which cues may serve vicariously to mediate between unobservable cause(s) and observable effect(s). When cues are continuous, a common form of the measurement of vicarious mediation is in terms of the inter-correlation (intra-ecological correlation) among cues; when cues are dichotomous, the relative frequency or the probability of co-occurrence may be used as measures of redundancy. Large numbers of intersubstitutable, contemporaneous and thus redundant perceptual cues are apt to be found in naturalistic tasks. As cognitive task conditions become increasingly artifactual, that is, managed, or constructed , by human beings for human beings, the naturalistic form of vicarious mediation is generally eliminated from the task in the

interests of efficiency because intersubstitutability provides unnecessary, redundant, and thus wasteful, information. (See, for example, Simon, 1969, on "The Sciences of the Artificial.")

There is an important distinction between the vicarious mediation that appears in naturalistic tasks and the redundancy that is built into artifactual tasks. Naturalistic vicarious mediation can be called "horizontal" because it involves the co-variation among cues presented contemporaneously, whereas artifactual redundancy can be called "vertical" because it involves the subsequent occurrence of cues that appear sequentially, and then only if needed. (For example, if this instrument fails, then read that one.) Even if the information is displayed to minimize risk (e.g., 3 clocks in the navigational quarters of a ship, or back-up mechanisms in large aircraft or space ships) artifactual redundancy is arranged so as to provide the correct amount (in a cost-benefit sense). Artifactual redundancy thus differs from naturalistic vicarious mediation in that the former provides a step-wise use of mechanisms, in contrast to contemporaneous vicarious mediation in naturalistic tasks.

The distinction between horizontal vicarious mediation and vertical redundancy can be seen in relation to various approaches to judgment and decision research and the methods tightly linked to them. For example, Social Judgment Theory and Information Integration Theory tend to display a (comparatively) wide array of information (several cues) wholistically and contemporaneously, thus providing horizontal vicarious mediation. On the other hand, Psychological Decision Theory and Behavioral Decision Theory (see Hammond et al., 1980, for explanation of those terms) tend to display information from a smaller set of cues sequentially, thus providing vertical redundancy, if and when it occurs.

4. Cue distribution characteristics. The usual statistical considerations (variation, kurtosis, skewness, etc.) apply here. The effects of these task characteristics are seldom examined in judgment and decision research, despite the results of early work indicating their importance (see, for example, Slovic & Lichtenstein, 1971.)

In those tasks in which (a) the subject observes an outcome, or (b) the researcher knows the outcome (either as a result of empirical observation or by calculation through the use of a rational model such as Bayes' Theorem) or (c) both, the following parameters of (a) the shape of the functional relation (i.e., the function form) that exists between each cue and the outcome, (b) the ecological validity between each cue and the outcome (as well as other statistical characteristics such as variation, shape of the distribution, etc.) and (c) the nature of the organizing principle that encompasses the relation between cues and outcomes (e.g., Bayes' Theorem, a regression equation, a physical law (of gravity) or an arbitrary rule as in concept formation tasks, among others. The organizing principle embedded in various tasks is clearly a critical aspect of such tasks because of its strong effect on the various properties of cognition indicated in Table 2. (Cf. remarks on the Principle of Parallel Concepts in Hammond et al., 1975.)

Predictions. Those task properties on the left in Table 1 will induce in the single-system (no outcome) case the cognitive properties indicated on the left in Table 2, and, correspondingly, the behaviors indicated on the left in Table 3 will be induced, similarly for the double-system case. (The same is true for the right hand side of Tables 1, 2, and 3.)

Explanation of the relation between complexity of task structure and predictions of behavior.

Tasks which require that the subject make an inference over a series of entangled dimensions that must be disentangled by unaided cognitive activity induce low control, unconscious data processing and other activities indicated in Table 2 because such task circumstances resist disentanglement by analytical means. That is, the subject cannot separate causality by physically holding constant each of several interdependent variables while varying another. Indeed, in such tasks the subject will seldom have available an explicit model of the task which identifies the variables, and will be even less likely to be able to know, or to learn, the nature of, or amount of, interdependence between the variables in question. In short, when proximal-distal separation is deep, knowledge of the causal texture of the environmental structure will be low-to-non-existent. Absence of such knowledge induces low cognitive control (because there is uncertainty about what leads to what); unconscious data processing (because of the lack of an organizing principle); vicarious functioning (because the lack of an explicit task model permits shifting cue utilization); rapid data processing (because no organizing principle is available that would require slow, step-by-step organization of the data throughout the causal network);

raw data or events are stored in memory (because there is nothing else to store); if metaphors are employed, they will be predominantly pictorial (because these provide the only available means of organization); right hemisphere activity will be predominant (because pictorial imagery is largely a function of right hemisphere activity); and if a stable judgment policy is eventually achieved it will be resistant to change (because new information can be readily absorbed into such a system without directly contradicting any aspect of it).

Additionally, the contemporaneous display of a large number (N = 5+) of cues presents a large data-processing demand. If the subject does not bring to the task an organizing principle that will permit the cues to be categorized in a fashion that effectively reduces their number, then the information-processing demand will diminish cognitive control, and thus induce inconsistency, unawareness, and the employment of a linear model as an organizing principle. If the subject does bring an organizing principle to the task that will reduce the number of cues and place them in a functional context, then greater cognitive control, consistency and awareness will be induced, despite the presence of a large number (N = 5+) of cues.

On the other hand, the display of a small number of cues (N = 4 or less, the threshold depends on other task properties) permits the organization of the information by means of a principle; therefore cognitive control can be enhanced, together with greater consistency, and awareness of the principle. Nonlinear organizing principles are more apt to be used by subjects when there are a small number of cues; for example, multiplicative (synergistic) models of cognitive activity rarely, if ever, occur when more than two cues are displayed simultaneously. (See Table 2 for a complete list of cognitive consequences following from varieties in the complexity of task structure.)

Ambiguity of task content. Tasks vary with respect to the extent to which they present material that the subject understands, or believes s/he understands; the less the subject believes s/he understands, of course, the greater the ambiguity of the task for that subject. There are several parameters that define the subjective ambiguity of task content; in the single-system case the most important of these is (a) whether the subject brings to the task a conscious awareness of an organizing principle that permits the information to be used in what the subject believes is an appropriate way. Additionally, (b) the existence, in principle, of an empirical or logically deducible outcome by which the subject's judgment or decision can be compared, (c) prior familiarity with the task content, and (d) the information given to the subject about the task at the time the subject first encounters it (feed-forward). In the double-system case in which feedback is provided to the subject and, therefore, in which learning is in principle, if not in fact, possible, additional parameters include: (e) type of feedback, and (f) the degree of accurate prediction (judgment) possible. Each is discussed in turn.

Availability of an organizing principle. A large difference in performance can be expected between a person who brings a conscious awareness of Bayes' Theorem or other statistical models to a proabilistic inference task and one who does not, or between a person who brings expertise with regard to the application of the principles of algebra and one who does not. (Larkin, McDermott, Simon and Simon, 1980, describe such differences). In either case, the questions are the same: Which, if any, organizing principle does the subject bring to the task? To what extent is the principle adequate? To what extent can the subject learn or otherwise acquire from task feedback or another person an organizing principle appropriate to the task? What are the consequences of bringing different types of organizing principles with different degrees of competence to various types of tasks? These questions have inspired cognitive psychologists from the start and they have used a wide variety of tasks in their efforts to answer them. The results of research indicate that the organizing principle evoked by the task depends not only on the "shape" of the task, the technique used to evoke it, but also the researcher's notion of how an organizing principle functions.

In the work of the Carnegie-Mellon group, for example, the task conditions always require that the subject develop, sooner or later, the conscious awareness of an analytical organizing principle, for the subject is always required to describe it (or them) verbally. The technique for discovering organizing principles, verbal protocol analysis, is thus tied to the putative cognitive process discovered, as well as to the task conditions employed. (The study of the application of an organizing principle to a task may involve the use of eye movement analysis as well; see, for example, Larkin et al., 1980.) In the work of virtually all judgment and decision researchers (in contrast to those working on problem-solving, or thinking), task conditions are arranged so that subjects are unable to bring to the task, that is, do not have available (cf. Tversky and Kahneman, 1973), analytical organizing principles, either because the subjects are naive with regard to the task, or circumstances prevent or inhibit them from employing principles already held, or seeking the principles that would be effective. The heuristics putatively evoked by such task conditions in which subjects are unable to employ (or discover) the correct (i.e., optimal) organizing principle have been described by Tversky and Kahneman (1974) and others, (e.g., Slovic et al., 1977; Nisbett and Ross, 1980).

Task conditions have to be considered in detail with respect to the utility of a priori organizing principles, as well as with respect to the conditions that evoke them or permit their use. For example, Simon (1969; see also Larkin et al., 1980) has shown that chess experts are far better than novices in remembering the patterns of pieces on the chess board, unless the pieces are arranged randomly, in which case they are no better than novices. The organization of task conditions, therefore, makes a difference with regard to whether an organizational principle will be evoked that permits "chunking", and thus permits effective recall or recognition. Similarly, a shift in distal aim with respect to identical task conditions makes a difference. For example, when four expert highway engineers were asked to make judgments about the amount of traffic a variety of highways differing in lane width, etc. would be able to carry (i.e., the mobility of the highways), it was found that the engineers were in high agreement with themselves and one another over a series of 50 judgments. But when asked for judgments of the safety of the same 50 highways, inter- and intra-engineer agreement dropped markedly (see Adelman, Deane and Hammond, 1976). The difference is due to the fact that judgments of mobility evoked a familiar organizing principle (a known algorithm), but judgments of safety did not because the engineers knew of none. Thus it might be said that these engineers were expert with regard to mobility, but less expert with regard to safety. In short, the subject's opportunity to employ an organizing principle will have a critical effect in determining whether the subject will exhibit the properties of intuitive or analytical cognition, and various elements thereof.

Apparently, no one doubts the need for the concept of an organizing principle, for it can be found in the conceptual repertoire of every approach to the study of cognition--from problem solving to social perception. The critical question seems to be: What organizing principle is it that accounts for the cognitive activity of the subject? From the point of view taken here, the answer is: the ambiguity structure of the task selects the organizing principle that will be employed by the subject, an answer that is based on the comprehensive view offered by Brunswik and Heider (and also by the early (1956) Simon); and, indeed, that answer is the cause for developing the theory of task structure presented here. Present circumstances are such, however, that the name of the researcher is the best clue for guessing the organizing principle that will be discovered in any research paper. That is, Anderson (1974) will discover that organizing principles are best described as an intuitive form of "cognitive algebra" while Edwards (see Hammond et al., 1980) will discover that Bayes' Theorem (conservatively employed) is the organizing principle people intuitively apply, while Tversky and Kahneman (1974) will discover that people intuitively employ "heuristics" that lead to the "biases and shortcomings" emphasized and generalized by Nisbett and Ross (1980), while Keeney and Raiffa (1976) will indicate that the Subjective Expected Utility model is the organizing principle people <u>should</u> employ (and <u>will</u> employ if aided to do so), while Kelley (1973) will find that persons will employ intuitively the same organizing principle (the factorial design implied in Mill's Canons) that scientists do and are thus "intuitive scientists", while Peterson and Beach (1968) will find that persons organize information as if they are "intuitive statisticians", while Newell and Simon (1972) will discover that people use "list structures" as organizing principles. And there are others. Should a curious student push on to inquire how it is that each of these investigators persistently discovers the same singular organizing principle to be useful throughout his research, the answer will be found readily enough; tasks are as firmly tied to investigators as are organizing principles. In short, the same investigator continues to use the same method and procedure in connection with the same task structure to rediscover that their subjects are employing the same organizing principle.

At no point does this effort toward the unification of research in the field of cognition hold out more promise than in connection with the coordination of present views regarding organizing principles and their links with the ambiguity of task structure. For if it is indeed true that investigator-organizing principle-method and task structure are clustered, then we may be further along than we think. What needs to be done is to discover the nature of the task structure employed by various investigators, locate these structures on some dimension (or dimensions) such as the one offered here (or some other), and apply the results of the research that are associated with each region of the task continuum. In a rough approximation to this procedure we shall find Simon's organizing principle, "list structure," applicable to the analytical end of the continuum offered here, the SEU model applicable to the left of Simon (where the applications of Keeny and Raiffa occur) and where the research on probabilities and utilities by Edwards and his colleagues has occurred, and as the structural aspects of the tasks become more ambiguous the work by Kahneman and Tversky, then the work by Anderson, who has concerned himself almost entirely with those tasks which contain no analytical structure, and thus no organizing principle. Work by the present author and colleagues, which involves no commitment to a specific organizing principle, fits somewhere in the center of this continuum (cf. Hammond et al., 1980).

We must hasten to add, however, that although the potential application of an organizing principle is highly important in determining the cognitive activity of the subject, it does not <u>wholly</u> determine that activity.

<u>Existence in principle of a task outcome by which the subject's</u>

judgment can be empirically compared. If the form of the task does not include an empirical or logically determined outcome, the subject is free to engage in a range of cognitive activity not present in circumstances where an outcome will permit empirical or logical evaluation of the subject's cognitive effort. Additionally, it is important to distinguish between those judgment tasks in which there is an action that interacts with the outcome from those in which action does not interact with the outcome. For as Einhorn and Hogarth (1978) have shown, actions that affect the observed outcome may make learning impossible, a matter taken up below in connection with evolutionary epistemology.

Prior familiarity with task content. Different degrees of prior familiarity will result in the differential likelihood of the application of various organizing principles; that is, the differential likelihood of the application of the various heuristics that follow from expert knowledge and those that do not. Larkin et al. (1980, p. 1338) differentiate the semantics of task content from its syntax, and indicate that different results may follow from differential familiarity with each.

Information given to subject (feed-forward). Judgment and decision research provides a variety of types of information that define the task for the subject, or as Simon (1969, et seq.) puts it, delimits the "problem space" for the subject. Thus, for example, some researchers provide no prior information regarding the task (seeming to rely on the tabula rasa assumption) for their subjects while others on occasion train their subjects in an effort to establish a specific cognitive system with specified values for certain parameters, both values and parameters being specified a priori. Work by Social Judgment Theory researchers contains more of this type of feedforward than any other approach; it is particularly evident in its studies of interpersonal learning and interpersonal conflict carried out by Brehmer (see Brehmer and Hammond, 1977; also Hammond et al., 1975), in which two subjects (unwittingly) learn to develop different weighting systems and to employ different function forms prior to being engaged in a joint judgment task. Throughout this work, however, a constant organizing principle (a linear model) is employed, thus restricting generalization to such conditions.

Edwards (1961) called attention to the role of outcomes in providing feedforward nearly 20 years ago in an article entitled "Costs and Payoffs Are Instructions", in which he indicates that his purpose is to " . . . state the problem of internally contradictory or ambiguous instruction; . . . [and show] how the specification of costs, payoffs and exchange rates solves it . . . ." (p. 275). Much of the work in studies of choice behavior does provide feedforward, or instructions in the form (probabilities and utilities) Edwards recommends.

Feedback. As indicated above, the strong tradition of identifying outcomes as reinforcers, and emphasizing the role of reinforcement in learning, has slowed researchers in cognition from breaking with this singular, undifferentiated concept of feedback. Provisions of the correct answer (knowledge of results) has long been accepted as the only type of feedback a researcher might conceivably apply when investigating learning. But, as indicated by Hammond, Hursch and Todd (1964) in judgment tasks in which there are cues of limited ecological validity, there are a wide variety of types of feedback that can be provided to the subject regarding the structure of the task. And, of course, in those cases where the information value of outcomes is weakened by an uncertainty relation between cues and outcomes, information about task structure (e.g., ecological validities, task function-forms, etc.) can, and often does, carry more information, and thus may be expected to enhance learning (see, for example, Hammond, 1971, Deane, Hammond and Summers, 1972; see also Gillis, Stewart and Gritz, 1975, in which the same concepts and techniques are shown to enhance the learning of psychotic patients). Indeed, Hammond, Summers and Deane (1973) have shown that outcome feedback can be detrimental to learning in multiple-cue probability learning tasks. (See also Howson, 1979.)

Predictions. As indicated above, task properties on the left in Table 1 induce those cognitive properties on the left in Table 2, with the behavioral consequences indicated on the left in Table 3.

Explanation of the relation between ambiguity of task content and predictions of behavior. Tasks which are highly subjectively ambiguous are those for which the subject cannot apply an organizing principle--of whatever variety. Without an explicit awareness of an organizing principle that can be brought to bear on the task, the subject is apt to employ (unwittingly) a linear model for that purpose, for it seems that the conscious application of a random system is impossible for human beings. (The evolutionary implications of this assertion are explored below under Premise 5.) To the extent that the task evokes or induces a conscious organizing principle, such awareness will enable the subject to exercise a high degree of cognitive control. Such awareness will also permit the storage of complex organizing principles (rather than events). The use of such principles is apt to be accompanied by verbal and quantitative metaphors, and thus include left hemisphere activity. Because they are the product of highly controlled cognitive activity, the judgments that arise in such situations are apt to be readily affected by a change in task conditions, or new information. (Cf. above remarks concerning resistance to change.)

As noted above in connection with (a) the complexity of task structure and (b) the ambiguity of task structure, other aspects of cognition are affected by task structure, and I now turn to a further description of the parameters of the form of the task.

Form of task presentation. There is wide variation between (but little variation within) researchers with regard to the form in which they present cognitive problems to their subjects. Not only do the researchers disregard the obvious implications of such variations, they treat the results obtained in connection with their favorite form of presentation with a high degree of finality. This stubborn refusal to encompass methods employed by others, and to employ only those invented by oneself (or one's teacher) was noted by Slovic and Lichtenstein in 1971 and described in some detail by Hammond et al. (1980). It can currently be seen in extreme form in Simon's pronouncement in Larkin et al. (1980) that "Expertness probably has much the same foundations wherever encountered. As in genetics, we learn much about all organisms by studying a few intensively. Chess, algebra, and physics are serving as the Drosophila, Neuropora and Escherichia coli of research on human cognitive skills" (p. 1336). The hypothesis that expertness has the "same foundations wherever encountered" is certainly a plausible one and no doubt will be subject to persistent empirical inquiry. But the suggestion that the cognitive operations demanded by chess, algebra, and physics exhaust the concept of expertness or "cognitive skill" provides yet another painful example of generalizing the results obtained with one form of problem and one method to those obtained with all forms of cognitive problems and methods for analyzing behavior in relation to them. Instructive and informative as the results obtained by verbal protocol analysis in relation to problem-solving may be, such an unwarranted methodological generalization will seem implausible to the other researchers in the field who are not employing "chess, algebra or physics" as a means of studying cognitive skills. It is implausible because no consideration is given to the variation in the form or structure of tasks, not to mention variations in complexity or ambiguity described above.

Simon's earlier (1969) position was quite different, for he then argued that it is the structure of the environment that selects the behavior, thus: "The apparent complexity of [man's] behavior over time is largely a reflection of the complexity of the environment in which he finds himself" (1969, p. 25). And in 1975 Simon asserted that

Discovery of what subjects learn can be approached

> experimentally but important preliminary insights can be gained by analyzing the structure of the task itself to determine the possible alternative ways of performing it. . . . [and] a formal analysis of the environment can help define the differences in the demands that different methods of task performance place upon the subject. (p. 268; see also Simon & Reed, 1976)

This position (similar to Premise 2 above) suggests that variations in the complexity of the task lead to variations in behavior. From this point of view, it is incumbent upon researchers to develop a theory that specifies the relation between differences in the form or structure of the task and differences in cognitive activity. That is the attempt being made here.

Differences in task complexity and ambiguity and predictions regarding their cognitive and behavioral consequences were indicated in the two sections immediately above. In this section we turn to specific variations in the form in which tasks are presented to subjects.

The several parameters of form include (a) type of task decomposition, (b) type of cue data and judgment required, (c) type of cue definition, (d) response time permitted or implied, and (e) type of feed-forward. Each is discussed in turn.

Task decomposition. There are two general ways in which tasks are "decomposed", that is, broken into their constituent parts by the researcher. Each form leads to a different type of cognitive activity, and a different method of the analysis of that activity.

One form of task decomposition is a priori; that is, the researcher identifies the parts of the task (e.g., probabilities and utilities, diagnostic information and base rates, or means and ends) for the subject before the subjects exercise their judgment.

A second form involves a posteriori decomposition. In this case, presentation of natural circumstances, or photographs of them (see, for example, Shanteau and Phelps, 1975) or actual persons or places provides the task materials. Decomposition of the task materials may never be carried out for the subject, but in any case, such task decomposition is a posteriori in that the constituent parts of the task are identified for the subject (if they are identified at all) after the subject engages in whatever cognitive activity the task demands.

Linked closely to a priori and a posteriori decomposition of the task is the a priori and a posteriori decomposition of cognitive activity. Thus, for example, when the experimenter decomposes the task by instructing the subject that s/he is expected to think about the problem in terms of the probabilities and (possibly) utilities associated with various choices, the experimenter decomposes the subject's cognitive process in the same way. After being pro[illegible] with the information, the researcher may exhibit the obt[illegible]ned decomposed process (in the form of a decision tree or similar) for the subject's inspection. In this way, the subject's cognitive activity regarding the task is decomposed into its elements (probabilities and utilities) prior to the subject's overall ("rolled back") choice in connection with an a priori decomposed task.

A posteriori decomposition of the subject's cognitive activity, on the other hand, occurs in connection with the wholistic displays of information mentioned above. That is, after a number of displays of numerous cues have been presented serially, then the researcher/analyst "decomposes" the cognitive activity of the subject into its constituent parts (weights, function forms, organizing principles, such as, for example, algebraic equations or list structures, etc.)

A priori task decomposition induces the cognitive properties on the right in Table 2, because it involves the presentation of a few cues sequentially (see Table 2). A posteriori decomposition, on the other hand, induces the cognitive properties indicated on the left in Table 2 because such decomposition allows the subject to arrive at a judgment in the face of many cues contemporaneously displayed without prior definition.

Type of cue data and judgment required. In tasks that include continuous cues, less cognitive control is required for utilizing information from continuous gradations than from dichotomous ones. That is, in the case of continuous cues, adjacent scale categories do not often point in different directions, but in the case of dichotomous cues they can and usually do; that is why the information is displayed dichotomously (cf. Brunswik's analogy with trains switching at junctions, or any computer simulation of cognition). Therefore, more cognitive control is induced in the latter case than in the former. Additionally, artifactual tasks that offer dichotomous cues are often constructed so that sequential cognitive operations are induced; e.g., if cue A reads "off", then look for the information provided by cue B.

The same considerations hold with regard to the judgment categories that the task requires of the subject; continuous response scales induce the cognitive properties on the left of Table 2, dichotomous response scales induce the cognitive properties on the right of Table 2.

Types of cue definition. Of particular importance is the question of who measures the information provided: Must the subject make a perceptual appraisal of quantity? That is, must the subject perceptually measure the number of wrinkles in a face, perceptually measure the age of the person-object, or are the various levels or quantities of cues measured for the subject by the researcher and thus presented in quantitative form.

Perceptual measurement occurs most frequently in naturalistic tasks presented by social circumstances, or those environmental circumstances (e.g., a wilderness) in which data are not organized and measured by human beings for human beings. Since perceptual measurement induces a largely unconscious form of data processing, less cognitive control can be applied in these circumstances and thus the activities associated with perceptual measurement are likely to be those indicated on the left of Table 2.

Response time permitted or implied. Few judgment and decision researchers (apart from those studying psychophysics) make a point of recording response times. Yet it is clear that the research circumstances in which most subjects find themselves imply that they are not expected to take more than 15-45 seconds to reach a judgment, and, in all likelihood, they seldom do. Problem solving researchers, on the other hand, often record judgment times (at least when a computer display is involved) because (a) time-to-solution is often a dependent variable presumed to be affected by the independent variable(s) of the experiment,and (b) they believe that there may be wide individual differences in time taken to reach a solution. The encouragement of short or long response time in judgment and decision research, however, is an experimental condition that must be searched out and often can only be guessed at. For example, if a judgment task is described to a subject, and the subject is then shown a stack of, say 400 cards, and if the subject knows that s/he has a limited time, say, 50 or 100 minutes in which the judgments are to be made, a brief response time will have been implicitly but strongly encouraged. Yet the very same task might be given under conditions in which a long response time is implicitly encouraged; say, for example, the subject is required to judge, 20 profile-cards/day for 20 days. Although variations in time are seldom so great as this (with all other task features held constant), they do occur; the conditions that encourage brief or long response times do vary widely without clear indications of exactly what they were, or why they were employed. For example, contrast process tracing task conditions with Bayesian tasks, or with tasks in which subjects are required to make judgments about people who are described in 4 - 5 sentences. Judgment and decision researchers seldom delineate their generalizations about their subjects' cognitive activity with respect to the time dimension. Of course, brief response times induce the cognitive properties on the left of Table 2, long response times imply those on the right. (The matter of <u>time</u> is developed in more detail below on connection with Premise 4.)

<u>Feedforward</u>. There are a wide variety of means for indicating to the subjects how they are to approach their task. That is, researchers may provide careful descriptions of the instructions they gave their subjects,but the psychological implications of the instructions (e.g. regarding time) may not be made explicit. This omission is particularly important for the amount of control the subject is expected to exercise over his/her cognitive activity. Do the instructions or the task materials imply that the subject <u>should</u> possess an organizing principle that will permit analytical cognitive activity? Or do the instructions imply that little is expected other than (unpenalized) guessing? Does the time provided imply that the subject is expected to find or create, an organizing principle, or do they imply that no organizing principle is expected?

<u>Predictions</u>. (See Tables 1, 2, 3)

<u>Explanation of the relation between the form of the task and predictions of behavior</u>. A posteriori decomposition of cognitive activity induces low cognitive control and related cognitive properties (see Table 2) because it is generally employed in association with a large number of cues contemporaneously displayed in relation to task material for which the subject has no organizing principle which can be applied. Because decomposition occurs after a series of judgments have been made, data processing during each trial

is generally rapid, and of a low level of awareness. A priori task decomposition is generally carried out in connection with a prior cognitive decomposition and thus induces slow but careful choices; the subject generally can provide reasons why one branch of the decision tree is chosen over another. By elevating the process to conscious awareness by requesting a direct arrangement of weights to consciously selected dimensions to which weights must be consciously assigned, the properties of cognition indicated on the right in Table 2 are induced.

Summary. Given that (a) cognition is an activity that occurs on a continuum (Premise One) and that (b) most judgments and decisions combine elements of both intuition and analysis into quasi-rational cognition (Premise Two), Premise Three asserts that the continuum permits the establishment of an ordered relation between (a) the properties of cognitive tasks, (b) the properties of cognitive activity, and (c) the judgment and decision behavior that follows. Such properties were then specified, thus making it possible to predict and explain the behavior that results from various task circumstances. The identification of task conditions and the specification of the relation between task conditions and judgment and decision behavior provides a critical step toward unification. For this step will make it possible to investigate the existing empirical relations between task properties and behavior that have already been discovered by different investigators. If it is true that different investigators have typically employed different tasks, and that these tasks can be ordered on a continuum, then it follows that the task continuum may well have been explored already. To what extent the predicted behavior will be found to occur in these studies is the topic of an investigation already underway; it will be described in a subsequent Technical Report.

Premise Three makes that exploration possible. At this point, it is necessary to consider in further detail the matter of time as a critical aspect of cognitive tasks.

Premise 4. Cognitive activities may move along the intuitive-analytic continuum over time; as they do so, the relative contributions of intuitive and analytical components to quasi-rationality will change. Successful cognition inhibits movement, failure stimulates it.

In his essay devoted entirely to the analysis of Darwin's imagery in relation to the "Tree of Nature," Gruber (1978) notes that "It took about fifteen months from this point [the drawing of the diagram] until Darwin grasped the principle of natural selection as the key operation giving the tree of life its form" (p. 127). And although Gruber studied Darwin's entire life span, he examined this fifteen-month period of Darwin's notebooks with particular intensity.

This is certainly an atypical approach to the study of cognition. For virtually all researchers in experimental psychology have chosen to use cognitive tasks that require no more than the college sophomore's 50-minute hour at most, and it is not unusual for tasks to require only minutes of cognitive activity. Indeed, because the problems they employ are so limited in time (and scope), researchers seldom bother to record the time that their subjects take, unless the problem is so reduced that it is appropriate to record time in seconds or milli-seconds. If we simply observe the length of time (years, in many cases) that many significant problems have required (and received) from their subjects, it is obvious that present tasks used in judgment and decision research are unrepresentative with respect to the dimension of time.

On the other hand, many judgments and decisions are made in brief periods of time; the last few minutes of several weeks or months of discussion may be the effective time period. And often time simply isn't available for thought. Therefore, much of the work that involves tasks that require only moments is in fact representative of tasks outside the laboratory. The restriction of research to those situations that permit little time points to one obvious restriction to generalizations about the cognitive capacity of human beings. A more subtle restriction of generalization occurs in connection with the use of tasks that require little time from subjects because the subjects would not know how to use additional time if it were available to them. Many of the tasks used by Tversky and Kahneman (1974) and others to demonstrate the use of heuristics are of this type. Because the problem is stated in a few brief sentences, and because the proper solution requires that the subject bring a specific organizing principle (Bayes' Theorem) to the task, there is little the subject could do with an extended time period, even if it were available. For unless the subject has the means to invent the proper analytical model, more time would be of little use. Still, one must be cautious, as the following anecdote will indicate. A research assistant was presenting a group of subjects with a task used many times in studies demonstrating that "base rates are ignored" and found one subject stubbornly ignoring the implied 50-minute time limit instead; this subject (with little or no training in statistics or mathematics) discovered Bayes' Theorem (in roughly 1 hour and 20 minutes) and thus produced an analytical solution to the problem. How often such solutions might occur if it were possible to arrange for subjects to take hours, days, or weeks to work on such problems, we don't know.

The dimension of time is of critical importance because people need time to use the full range of their cognitive capacities. And if judgment and decision researchers typically employ short periods of time, students of problem-solving behavior, on the other hand, often use long periods, and are thus able to observe movement along the cognitive continuum.

Consider, for example, the behavior of persons attempting to cope with a highly analytical task in which a definite answer is being sought. It is common to observe that problem-solvers proceed analytically, until failure occurs, then return to pursue an alternate path, the potentials of which are made more or less obvious by the task materials. (See any computer program built to simulate human problem solving, e.g., Newell and Simon, 1972.) When the first efforts at analysis fail, the subject's cognitive activity moves away from analysis to quasi-rationality; that is, the subject's cognitive cognitive activity begins to acquire elements of intuitive cognition (see Tables 1-3, above); and, insofar as the subject is concerned, the task itself changes. If the problem is so difficult that analysis fails to provide a solution, then the subject's cognitive activity may move far enough along the cognitive continuum to become predominantly intuitive; cognition may consist almost entirely of pictorial imagery, as in the case of Darwin's "Tree of Nature." (A better known example of the role of pictorial imagery is provided by Kekule's discovery of the six-carbon benzine ring.)

If the problem-solver finds this form of cognitive activity provides an idea to be tested, and thus sufficient to move him/her back to an analytical mode (as, according to Dyson, it was in Feynman's case), the subject may be said to move, not necessarily continuously or smoothly, from intuition through quasi-rationality to the context of analysis.

The concept of movement back anf forth from intuition to analysis was described by Polanyi, thus:

> To start working on a mathematical problem, we reach for pencil and paper, and throughout the stage of Preparation we keep trying out ideas on paper in terms of symbolic operations. If this does not lead straight to success, we may have to think the whole matter over again, and may perhaps see the solution revealed unexpectedly much later in a moment of illumination. Actually, however, such a flash of triumph ususally offers no final solution, but only the envisagement of a solution which has yet to be tested. In the verification or working out of the solution we must again rely therefore on explicit symbolic operations. Thus both the first active steps undertaken to solve a problem and the final garnering of the solution rely effectively on

computations and other symbolic operations, while the more informal act by which the logical gap is crossed lies between these two formal procedures. However, the intuitive powers of the investigator are always dominant and decisive. Good mathematicians are usually found capable of carrying out computations quickly and reliably, for unless they command this technique they may fail to make their ingenuity effective--but their ingenuity itself lies in producing ideas. Hadamard says that he used to make more mistakes in calculation than his own pupils, but that he more quickly discovered them because the result did not look right; it is almost as if by his computations he had been merely drawing a portrait [italics mine] of his conceptually prefigured conclusions. Gauss is widely quoted as having said: "I have had my solutions for a long time but I do not yet know how I am to arrive at them." Though the quotation may be doubtful it remains well said. A situation of this kind certainly prevails every time we discover what we believe to be the solution to a problem. At that moment we have the vision of a solution which looks right and which we are therefore confident to prove right.

The manner in which the mathematician works his way towards discovery, by shifting his confidence from intuition to computation and back again from computation to intuition, while never releasing his hold on either of the two, represents in his hold on either of the two, represents in

> miniature the whole range of operations by which articulation disciplines and expands the reasoning powers of man. This alternation is asymmetrical, for a formal step can be valid only by virtue of our tacit confirmation of it. Moreover, a symbolic formalism is itself but an embodiment of our antecedent unformalized powers--an instrument skillfully contrived by our inarticulate selves for the purpose of relying on it as our external guide. The interpretation of primitive terms and axioms is therefore predominantly inarticulate, and so is the process of their expansion and re-interpretation which underlies the progress of mathematics. The alternation between the intuitive and the formal depends on tacit affirmations [cf. Whitehead and others quoted above] both at the beginning and at the end of each chain of formal reasoning. (Polanyi, 1958, pp. 130-131.)

N. R. Hanson (1958) also emphasized the movement of cognition, but in addition, emphasized the <u>continuity</u>, rather than the "alternation" that Polanyi spoke of, between the "intuitive and the formal." Thus, for example: "the <u>steps between</u> (italics mine) visual pictures and statements of what is seen are many and intricate. Our visual consciousness is dominated by pictures; scientific knowledge is primarily linguistic . . . Only by showing how picturing and speaking are different can one suggest how [they] may [be brought] together; and brought together they must be" (p. 25), as, for example, Darwin's diagram of the "Tree of Life" shows how they were indeed brought together in the construction of the theory of evolution.

These remarks are intended to raise the question of whether judgment and decision researchers have done justice to the role of time in relation to cognitive activity, whether they have given due consideration to the extent to which time is required for the relative contributions of intuition and analysis to cognition to become apparent. Theorists such as Gruber, Polanyi and Hanson and others (perhaps Simon?) might well dismiss the negative view of intuition drawn by current researchers (see the discussion under Premise 3 above) as providing a peculiar and misleading view of cognition, solely for the reason that current research practices provide only "snap-shots" of cognitive activity that are unrepresentative of what human beings can and do accomplish when they are allowed to have the time to employ all the characteristics of cognition that can be observed in everyday life. They would argue that if time were permitted, subjects would be able to make far better use of their pictorial imagery, as well as of their verbal and computational abilities, and the <u>interchange</u> between them. That is, time would allow analysis to test the results of pictorial imagery, and time would permit the return to imagery, and so on, thus permitting the cognizer to "work his way towards discovery, by shifting his confidence from intuition to computation and back again from computation to intuition, while never releasing his hold on either of the two," as Polanyi put it. Polanyi may have been wrong, of course, but at least he presented a theory that does not ignore the full range of cognitive activity that Brunswik and Heider described and that we are all familiar with. To what extent Hanson's emphasis on the "steps between" intuition and analysis turns out to be significant (the theory presented here expects them to be highly significant) remains to be seen.

Summary. The field of judgment and decision making that justifiably includes research on cognition of brief duration will have to incorporate the results of research that allows time for the full range of cognitive activity to be examined, or else risk being dismissed as devoting itself to gimmickery inappropriate to its subject matter. Fortunately, problem-solving research that emphasizes thinking does permit time for subjects to analyze, to resort to pictorial imagery, to test it and to recycle through this process. Therefore, it will eventually be possible, as Tables 1, 2, and 3 indicate, to relate the results of research on cognition of long duration to results of research on cognition of short duration and thus to come to understand the function of time. In short, the contributions from each type of research should be reciprocal, and thus aid the process of unification.

I turn now to a fifth premise; it deals with the relation of the cognitive continuum to brain function, and follows directly from the discussion of time.

Premise 5. Intuition, quasi-rationality and analysis are cognitive functions that have structural counterparts in the brain.

The brains of virtually all known species are divided brains, although differential function within cerebral hemispheres has been securely established only in man. And although it is uncertain at what point students of anatomy first became aware of the division of the human brain into left and right hemispheres, such awareness must have occurred long after the early philosophers (e.g., Aristotle) had made the distinction between intuitive and analytical modes of cognition. Indeed, the first clear delineation of the region of the brain responsible for verbal function was not made until Broca's (c. 1861) discovery. Thus, we have at hand independent developments that converge on a similar proposition.

The present state of this convergence can be seen in a recent article by Gur, Packer, Hungerbuhler, Reivich, Obrist, Armenek, and Sackheim (1980) in which they indicate certain major anatomical differences between the cerebral hemispheres, viz., there is" a greater density of cells . . . in the left . . . hemisphere, the surface of the planum temporale is larger and the sylvian fissure is larger in the left hemisphere, and the left hemisphere is more extensively fissured than the right." Gur et al. (1980) then show that there is "evidence . . . for interhemispheric differences in amount and distributions of gray and white matter." They relate these remarkable structural differences to differences in cognitive function, thus: "our results suggest that verbal-analytic functions are subserved by an organization that emphasizes processing or transfer within regions, whereas spatial-gestalt functions are subserved by an organization that optimizes transfer across regions" (p. 1227).

From the point of view of the Cognitive Continuum Theory, empirical research of this sort and the conclusions derived therefrom are valuable and thought-provoking because they constitute a challenge to develop further conceptual and empirical links between the right-left continuum of cerebral structure and the intuitive/analytic continuum of the complex cognitive activity involved in social judgment and decision making. Establishing that link may also include, if not require, the development of the pharmacology of cerebral function in relation to cognitive function. Evidence already exists that there are differential distributions of certain neurotransmitters in the hippocampus and the thalamus and in other structures within the brain, and this fact has led to research that indicates neurotransmitters do play a role in the differential function of the hemispheres (see e.g., Mandell, 1979). In short, scientific knowledge about the relation between the functions of cerebral hemispheres and certain cognitive activities already exists (although sceptics remain; e.g., Calloway, 1980, refers to research on this topic as "the currently stylish cult of cerebral asymmetry.")

Scepticism or doubt may follow from the fact that the empirical results are theoretically incomprehensible. For example, Gur et al. (1980) state that "no coherent body of data exists to explain why the left hemisphere specializes in analytic, logical and verbal functions . . . whereas the right hemisphere subserves holistic, gestalt, spatial functions." In short, we know much about what happens, but we still lack a "coherent" explanation for the empirical facts that imply that these relations between hemispheric function and behavior exist. Francis Crick (1979) suggests that "no coherent body of data exists to explain" differential cerebral function because "psychology attempts to treat the brain as a black box . . . . The difficulty with the black-box approach is that unless the box is inherently very simple a stage is soon reached where several rival theories all explain the results equally well." Crick further suggests that:

> What we know of the brain . . . tells us two things. The brain is clearly so complex that the chances of being able to predict its behavior solely from a study of its parts is too remote to consider. The same complexity also warns us that the black-box approach of pure psychology will have to be lucky if it is not to bog down. Psychology is essential. What the organism actually does we can learn only by observing it. Psychology alone, however, is likely to be sterile. It must combine the study of behavior with parallel studies of the inside of the brain. A good example is the work of Roger W. Sperry and his colleagues at the California Institute of Technology on "split brain" patients: people in whom the connections between the cerebral hemispheres have been severed. Another is the use of deoxyglucose to mark regions of the brain that are more active than the average while an experimental animal is performing some particular task. Thus can the study of neuroanatomy and neurophysiology be combined with behavioral studies. We must study both structure and function but study them within the black box rather than only from the outside. (p. 222)

We shall pursue Crick's suggestion regarding the "split-brain" patients in some detail below, but we must observe that Crick's admonition would have been better put, and will perhaps be better heeded, if he had indicated that both the "outside" and the "inside" of cognition were to be treated without oversimplification. (Recall the above quotations from Brunswik and Simon on equal treatment.) We are no better off if we pursue the details of the structure and function of the brain while treating the task environment as a "black box", than if we do the reverse.

The Cognitive Continuum Theory attempts to achieve symmetry by treating neither "outside" nor "inside" as a "black box". It attempts to extend the narrow task circumstances employed by brain/behavior researchers that provide proximal stimuli (so that plausible inferences can be made regarding precisely which parts of the CNS are involved at any given time) to include more distal circumstances that will justify the generalizations made to broad environmental conditions. Consider once more, for example, Gur et al.'s (1980) statement that "No coherent body of data exists to explain why the left hemisphere specializes in analytic, logical and verbal functions . . . , whereas the right hemisphere subserves holistic, gestalt, spatial functions." Surely this generalization (readily found elsewhere) implies that the results of research apply not only to circumstances involving e.g., direct differential retinal stimulation, but to situations that judgment and decision researchers would also describe as requiring "analytical, logical and verbal functions" as well as those that require "holistic, gestalt, spatial functions."

There is, in fact, a theoretical framework developed by the neuro-scientist Luria (1973) that suggests a link between brain structure and function that carries the potential for incorporating the results from the proximal stimulus studies and broader judgment and decision research. Luria makes not only the right-left distinction in the customary way, but also employs the anterior-posterior distinction to differentiate a representational (posterior) function and an executive (anterior) function. The representational system (located in this posterior cerebral cortex) is a system for "obtaining, processing, and storing information arriving from the outside world (1973, p. 43) whereas the executive system (located to the frontal cortex) is a system for "programming, regulating and verifying mental activity" (p.43). Furthermore, Luria postulates a law of progressive lateralization which states (p. 77) that the levels of cerebral functioning become more hemispherically differentiated as " 'the hierarchies' are ascended"; thus,

> The left (dominant) hemisphere (in right-handers) begins to play an essential role not only in the cerebral organization of speech, but also in the cerebral organization of all higher forms of mental activity connected with speech-perception organized into logical schemes, active verbal memory, logical thought--whereas the right (nondominant) hemisphere either begins to play a subordinate role in the cerebral organization of these processes or plays no part whatever in their course. (p. 78)

Luria's theoretical "law of progressive lateralization" is consistent with the concept of a cognitive continuum, and is in sharp contrast with the concept of a cognitive dichotomy; it also enriches the idea of a cognitive continuum by suggesting that the representational (posterior) and executive (anterior) functions are closely related to concepts employed, and results obtained, by judgment and decision researchers. For example, Luria's distinction between "representational" functions and "executive" functions parallel the conceptual distinction offered by Hammond and his colleagues between "knowledge" (that is, what a person knows) and "cognitive control" (his/her ability to execute that knowledge), a distinction that has empirical referents (see, for example, Hammond, 1971, Hammond and Summers, 1972; Hammond, et al., 1975; see also Hammond and Wascoe, 1980).

To sum up, much of the research in the field of localization of brain function refers to the same cognitive activity as that studied by judgment and decision researchers. And when the substance of the work of each is organized in terms of Cognitive Continuum Theory, a clear parallel emerges, because the general concepts of Cognitive Continuum Theory match those of the brain researchers. Thus, for example, Zaidel, one of the psychologists who participated in the extensive testing of the "split-brain" patients, concludes "hemispheric specialization falls on a continuum; it is a matter of degree rather than an all-or-none concept" (1978a, p. 261). This statement is a critical revision of the notion of a dichotomy, exactly as in the case of the revision of the intuition-analysis dichotomy. The fact that the concept of a cognitive continuum has appeared (probably independently) in both fields thus lends support to the ability of the Cognitive Continuum Theory to unify work not only within the field of judgment and decision research, but also between this field and work in the field of localization of cognitive functions in the brain.

On more concrete grounds there are at least three reasons why work in each field should enhance work in the other: (a) conclusions drawn from one field carry implications for conclusions drawn from the other, (b) predictions of future results that will be obtained in one field can be made from past work in the other, (c) the future course of research can be influenced by the communication of such conclusions and predictions. Each is discussed in turn.

How conclusions drawn from one field can affect conclusions drawn from the other. In both fields of research conclusions are drawn regarding the cognitive capacities of human beings. Cognitive psychologists elicit and evaluate these capacities by research methods that can be described in terms of two main clusters of features; one cluster tends to evoke predominatly left, the other predominantly right hemispheric activities. That is, one group of cognitive psychologists typically employs tasks that are highly decomposed, in a priori fashion, with the information, or cues, sequentially displayed in terms of words or numbers, thus measuring the task variables for the subject; from the point of view of brain researchers these cognitive psychologists are evoking predominantly left hemispheric activity. On the other hand, another group of psychologists typically employs tasks that are not decomposed a priori but are wholistic in form, with the cue information displayed contemporaneously in a pictorial fashion that requires the subject to measure the task variables perceptually (see Tables above for details); from the point of view of brain researchers, these psychologists are evoking predominantly right hemispheric activity. Different groups of cognitive psychologists are, therefore, studying different cognitive activities associated with different cerebral structures and functions with methods (more or less) appropriate for inducing these different activities. The results obtained by these two groups of cognitive psychologists should therefore not be expected to be the same (as they would be if one assumed that the same process was being studied by two different methods in order to provide method-independent results). Indeed, the results should not only be expected to be different, they should be treated as complementary. Different results and conclusions should therefore be treated as rounding out our knowledge of cognition, for they are the results that would be anticipated on the basis of research on hemispheric specialization.

How predictions of future results that will be obtained in one field can be made from past work in the other. As explained above in connection with Premise Two, positive and negative views exist regarding the intuitive capacities of human beings. It is not difficult to imagine that specialists in localization of function would find these points of view to be of interest and to inquire into the research circumstances that have produced them. And, as noted above, brain researchers might be expected to point out that since their past work has shown that different task characteristics induce different hemispheric functions, the different tasks used by judgment and decision researchers will place different demands on different cerebral regions, and thus place different ceilings on achievement, depending upon the <u>form</u> in which the material is presented to the subject. Thus, an upper limit, or ceiling, would be placed on achievement that would not exist if a different set of task characteristics were employed. Error patterns might also be unwittingly influenced by a choice of task characteristics that induced more cerebral activity in one region or another. Thus, for example, a task that induced left cerebral activity by presenting information wholly in terms of words and that offered no task-structure support (such as pictorial arrangements) for right cerebral activity, would result in lower estimates of capacity than would be obtained had both regions had support, or if the subject had an opportunity to seek such support.

Zaidel provides an example from his work with split-brain patients when he compares the performance of a patient [LB], who has only a right cerebral hemisphere, with a normal 6-year old who has the same total score on a test. He finds that "the error pattern in quite different. The [normal] 6-year old child will tend to be much more sensitive to the linguistic complexity of the message, the parts of speech, the syntactic complexity. The right hemisphere [patient], on the other hand, seems to be much more sensitive to the perceptual complexity, to the redundancy, and to the memory load of the message" (1978b, p. 17).

To provide normal persons with judgment and decision tasks that are perceptually complex, redundant and which induce a large memory load, then, is to ignore the capacity of the brain to cope with linguistic, syntactical complexity. Or, at the least, time and other structural supports must be provided if this capacity is to be allowed to be exercised. And, of course, the reverse will be true as well. Therefore, the negative conclusions that are drawn regarding cognitive capacities of human beings need to be conditional, not only with regard to the appropriateness of the analytical model with which they are compared (see Premise Two above), but also with regard to the extent to which the entire resources of the brain are permitted to be applied to the problem. (See also Friedman & Polson, 1980.)

Brain researchers seem to be more willing to acknowledge both types of conditions, as Zaidel's (1978b) remarks about the performance of the right hemisphere patient (LB) indicate: "if this is how well the right hemisphere can do in a non-redundant and carefully controlled test situation, imagine how well it can do in a freer and more redundant normal conversational situation" (p. 17). Brain researchers, in short, would predict that future generalizations about judgments and decisions would be found to be conditional upon the extent to which different types of cerebral activity are induced, evoked or otherwise permitted to be engaged in the task.

What predictions would a cognitive psychologist make with regard to future findings to be made by a brain researcher? Perhaps it is best to let a specialist in localization of function describe the present state of research in his field:

"What then is a general characterization of hemispheric specialization? There is as yet no definite theoretical

> answer. We have argued that modality- and material-specific models are inadequate and that information processing models are required [italics mine]. It was proposed [above] that the left hemisphere may specialize in combinatorial feature analysis and that the right hemisphere employs experience-reinforced or convention-bound template matching for visual and verbal alike and throughout the range of the cognitive system. Moreover, template matching in the right hemisphere has a poor internal model of its own solution processes and the right hemisphere is consequently deficient in error recovery relative to the left hemisphere. But the structural details of these cognitive styles remain to be found. (Zaidel, 1978a, p. 282)

Judgment and decision researchers would recognize immediately the relation between Zaidel's "general characterization of hemispheric specialization" as germane to their own work. But since judgment and decision researchers differ in their interests, I shall make my own predictions of future findings in brain research.

I predict that when "combinatorial feature analysis" is carried out brain researchers will find that organizational principles employed by the left hemisphere are similar to those described by Newell and Simon (1972); that is, they will be in the form of "list structures", or similar non-continuous functions. "Cognitive algebra" as, for example, developed by Anderson (1974) will not apply. The organizational principles employed by the right hemisphere will, however, include those described by Anderson's cognitive algebra, and varieties thereof (cf. Hammond et al., 1975). On the other hand, "list structures" and similar concepts will not apply to the work of the right hemisphere. (This prediction is developed further below in connection with "evolutionary epistemology".)

Moreover, it seems clear that "to have a poor internal model" of one's "own solution processes" is characteristic of cognition in multiple cue probability learning, and the "error recovery" (or learning by means of outcome feedback) is generally poor in such tasks. Since learning in multiple cue probability tasks is enhanced by the use of cognitive feedback (see Hammond, 1971), that is, pictorial representation of task parameters (such as weights and function forms), right hemispheric patients should perform as well as normals with feedback of this type, and their error patterns should be similar to normals.

Why the parallelism should affect the future course of research in both fields. If either of the above reasons for the exchange of information is approximately correct, then the future course of research in each field will be influenced by the work in the other. The first proposition indicated that cognizance of work in the field of localization of cognitive function can lend coherence to the results obtained in the field of judgment and decision research. The second suggests that results already obtained in each field can lead to predictions of future findings in the other. Tentative (and wrong) as these sample predictions may be, they lead both to a broadening of scope and a healthy restriction on the overgeneralizations that have already occurred in both fields. No judgment and decision researcher can read the far-ranging conclusions by Zaidel (1978b) without wishing s/he had achieved them, but also, perhaps, without wondering what methods were employed to reach them; for example: "There are important differences in the learning styles of the two hemispheres; the left is constructive, algorithmic, step-wise and logical. It benefits from narrow examples and from trial and error; it can learn by rule. The right hemisphere, on the other hand, does not seem to learn by exposure to simple rules and examples. Our studies show that it does not benefit from error correction [outcome feedback], perhaps because it does not have an internal model of its own solution processes, which it can then interrogate and update. It needs exposure to rich and associative patterns, which it tends to grasp as wholes [cognitive feedback]. Programmed instruction is certainly not for the right hemisphere, but I am not sure what is the proper method of instruction for our silent half. (p. 32)

These heady generalizations are bound to evoke suggestions from those judgment researchers who have developed computer-based decision aids that employ pictorial methods. They would suggest that these provide the proper method of instruction for the right hemisphere (see, for example, Hammond, 1971; Gillis, 1975; Hammond et al., 1975).

Suggestions will also be forthcoming, it is to be hoped and expected, from brain researchers with regard to one of the most critical aspects of judgment and decision research that has slowed almost to a halt, that of providing judgment and decision aids, or support systems, for policy makers. This is an area of research that should expand rapidly in the 80's; but past performance indicates that it may not, for it has developed very slowly so far. The basic ideas that guided the development of the computer-aided decision support systems available today were present ten years ago (see, for example, Hammond, 1971) as were the basic elements of programming and visual display systems used today. Progress is not hampered by lack of progress in the development of computer hardware or software; it is hampered by a lack of new ideas about how judgment and decisions can be improved. It may well be that brain researchers, who are so keenly aware of the relations between task characteristics and cerebral function, could provide those badly needed new ideas regarding the manner in which visual displays of cognitive material can aid cognitive reorganization. Given the recent achievements of the brain researchers, no serious effort to develop a decision support system should proceed without the contributions of a research worker in hemispheric specialization. Such contributions may provide the intellectual innovation that is so badly needed.

Beyond the obvious parallels in the laoratory work of each group lies a second field of mutual interest, evolutionary epistemology, to which I now turn.

Evolutionary epistemology. There has been a significant amount of research and discussion concerning the evolution of the brain in animals and man (see, e.g., "Evolution and the lateralization of the brain," Dimond and Blinzard, 1977), but the topic of the evolution of cognition, or "evolutionary epistemology" (a term invented by D. T. Campbell), has received only recent discussion, and, understandably, very little empirical research. Evolutionary epistemology has been made a firm part of the current work in the field of judgment and decision making by Einhorn and Hogarth (in press) in their chapter in the Annual Review of Psychology, for they made this topic the foundation of their review. Thus, for example (p. 3), they announce their intention to " . . . consider the complexities involved in evaluating discrepancies between optimal models and human responses, and, how persistent dysfunctional behavior is consistent with evolutionary concepts." (See also Simon, 1956, 1980, for references to cognition and evolution.)

The comprehensive view of cognition that includes the concept of quasi-rationality is directly pertinent to the evolution of cognition. Specifically, the properties of quasi-rationality imply that any species that may have acquired this form of cognition at some point in its evolutionary development would have a subsequent advantage in the struggle for survival because the properties of quasi-rational cognition are conducive to to survival in naturalistic environments. As will be shown below, this is a testable, falsefiable proposition, although, of course, this proposition assumes the truth of the evolutionary theory itself.

Quasi-rationality has survival value in naturalistic environments because it includes elements of both intuition and analysis; it thus simultaneously draws upon the different resources provided by each cerebral hemisphere (see remarks by Gur et al., Luria, Zaidel, above; see also Friedman and Polson, 1980). Indeed, as indicated above, quasi-rationality is marked by the these polar modes of cognition. By virtue of its partial dependence on contributions from perception and experience on the one hand, it accepts a wide variety of pieces of information but does not place all its credence in any one of them. On the other hand, by virtue of its partial dependence on analysis, it rejects apparent inconsistencies. Each piece of information, or cue, to distal events receives a degree of credence, or relative importance, or weight, or cerebral processing, in the organism's overall judgment about an object, or some state of affairs in the environment, and each judgment receives the analytical treatment time and analytical sophistication permits. Thus, quasi-rational cognition organizes various information into a judgment by means of a compromise between perception and thinking, between right and left hemispheric activity. More specifically, quasi-rational cognition organizes information by means of a weighted averaging mechanism, or "organizing principle" (see Premise 3 above); as a result, quasi-rationality may be effectively represented mathematically by what statisticians call a "linear model." And that conclusion leads to a link between evolutionary epistemology, brain function and mathematical models of adaptation.

The robust character of (quasi-rational) linear models of cognition. The outstanding characteristic of linear models in general, and the multiple regression model in particular, lies in what statisticians refer to as its "robustness." Such robustness is reflected in three major ways. First, even when the form of the model as an organizing principle is suboptimal (i.e., a nonlinear model provides a better fit to the predictor data set), the predictive validity of a linear model will generally be as good, or almost as good, as that of the optimal nonlinear model. Second, even when the functional relations between proximal cues and the distal criterion they predict are nonlinear, rather than linear, the organism that wrongly assumes that they are linear will not be far from accurate in its judgment, particularly if there is a substantial degree of uncertainty in the relation between cue and criterion. Third, even when the weights assigned by the organism are different from the optimal weights (i.e., cue utilization differs from the ecological validities of cues) the predictive validity of the organism that employed a linear model would be only slightly reduced. In short, an organism that blindly, persistently, and incorrectly applied a quasi-rational linear model would make approximately correct judgments over a wide variety of cognitive tasks; its distal achievement would be good, and very little learning would be required. Its chances for survival would therefore be higher than for organisms endowed with different organizing principles more closely fitted to a specific environment, if that quasi-rational organism lived in that form of naturalistic environment in which we suppose man to have evolved (about which more below). (The work that showed the robustness of the linear model in relation to judgment and decision research was carried out by Dawes & Corrigan, 1974; see also Dawes, 1979.)

The adaptive significance of quasi-rational rules is supported by Thorngate's (1980) computer simulation of "efficient decision heuristics". He shows that "most of the heuristics, including some that 'ignored' probabilistic information, regularly selected alternaties with highest expected value and almost never selected alternatives with lowest expected value" (p. 219).

There are, of course, limits to the robustness of quasi-rational cognition and its representation in the form of a linear model. These limits are created by the characteristics or properties of the cognitive tasks with which the organism must cope. From a formal, mathematical-statistical point of view, the predictive validity of the linear model is reduced when the task involves (a) a small number (n = 2) of highly valid cues that are related to the criterion in an interactive (i.e., contingent or synergistic) manner, or (b) a large number (n = 5+) of cues that have both positive and negative relationships to the criterion, (c) when there are substantial negative intra-ecological correlations among the cues (see McClelland, 1978; also see Hammond et al., 1980). and most important, when there is a substantial amount of uncertainty or unpredictability in the environment. In other words, quasi-rationality, and the linear model, fail progressively to provide the organism with good achievement as the cognitive task becomes more and more analytical in form.

Therefore, from a phylogenetic point of view we should anticipate finding that quasi-rational cognition would be most prevalent (and most successful) in naturalistic situations that do not require analysis, and least prevalent and least successful in artifactual situations, i.e., in cognitive tasks that do require analysis, particularly those created by man. From an ontogenetic point of view, we should anticipate finding that, all else being equal, quasi-rational cognition has a temporal priority in cognitive activity; that is, quasi-rational cognition appears prior to either intuition or analysis in judgment and decision making; in terms of cerebral activity, both hemispheres function first. Should a task or situation demand movement away from quasi-rationality towards either pole, cognition will return to quasi-rationality when either fails. (See the work of the philosopher Pepper, 1948, quoted in Hammond et al., 1980; for an exceptionally clear description of such cyclical movement also described above by Polanyi.)

To summarize: When survival requires adaptation to cognitive tasks that provide a large, positive matrix of cues of uncertain ecological validity, the organism that has acquired a cerebral system that can engage in quasi-rational cognition (represented by a linear model) will have an epistemological advantage that should be reflected in an evolutionary advantage, and thus a history of survival.

If we turn to an (admittedly cursory) consideration of the environmental circumstances and cognitive tasks with which an emerging homo sapiens had to cope, it is easy to imagine that such circumstances did in fact form a large positive matrix of cues characterized by large degree of uncertain ecological validity. At least, this would be so if the present assumption is true that man emerged and began to be a formidible contender for survival in a savannah-like environment. Moreover, intersubstitutability of means for survival (equifinality) characterize such an environment, and the potential for utilizing them (equipotentiality) characterize the quasi-rational linear model as well.

If quasi-rationality portends success in such an environment, its main characteristics (what developmental biologists call "plasticity", apparently equivalent to what judgment and decision researchers call "intersubstitutability"), should also aid the quasi-rational organism to cope with a changing environment. Those organisms that are not endowed with quasi-rational cognitive systems, and are required to function with systems that are analytical, are more dependent on single-cue mechanisms and therefore must change their cognitive system (either by learning or through genetic mutation) to achieve a better environmental fit if they are to survive. This is a change that may require more time (and luck) than the environment may permit. Quasi-rational organisms, however, can survive environmental change readily without changing their mode of information processing, that is, without learning, and thus without ontogenetic or phylogenetic change because the robust character of their cognitive activity permits reasonable accuracy of judgment over a wide range of conditions. (Cf. Thorngate, 1980, above; J. Shanteau and the present author are conducting a study similar to Thorngate's at Boulder, Colorado.)

At this point I turn to the question of what the evolutionary epistemology argument implies for the unification of current brain-behavior research and current judgment and decision research. In order to do so we need to consider in further detail the distinction between naturalistic and artifactual tasks.

Naturalistic vs. artifactual tasks. The term "naturalistic" is intended here to represent those tasks that are representative of nature without man's modifications, that is an ecology not directly arranged by man; an untouched forest, plain, or tundra, for example.

These naturalistic circumstances can be expected to induce pictorial, spatial, wholistic cognitive activity that is often not retraceable (see Gur et al., 1980 above) whereas the cognitive tasks constructed by man can be expected to (for they are intended to) induce systematic, analytical cognition; that is, they induce cognitive activity in verbal, quantitative and logical form because of the efficiency and retraceability of this form of information processing.

Thus, human beings have changed the array of cognitive tasks that are now encountered by human beings from tasks that are closer to the intuitive pole of the cognitive continuum to tasks that are closer to the analytical pole. The plains/forest environment, in which quasi-rational cognition evolved and is predominant, has been changed to a largely man-made environment in which cognitive tasks demand more and more analytical efforts. Driving a car or flying an airplane, for example, demands more analytical, go no-go cognition than walking, or riding a horse. In the one case there are a series of instruments that provide pointer-readings, in the other there are none. Thus, survival in western civilization is becoming increasingly dependent on "analytical, logical and verbal functions"; survival in the plains/forest environment was dependent on spatial imagery, "holistic, gestalt, spatial functions" in Gur et al.'s (1980) terms. Finding one's way home (or to someone else's home) in the modern city or countryside requires that one follow strictly laid out paths marked by obvious signals that have perfect ecological reliability and validity; finding one's way through the savannah meant reading a variety of redundant signs of low ecological reliability and validity. The task circumstances that selected those early human beings who possessed the appropriate quasi-rational cognition that enabled them to win out in the competition in the savannah have changed, and continue to change to favor those persons whose analytical capacities are greater. And the change is being brought about by those whose analytical capacities are greater. In short, the utility of the quasi-rational cognitive activity that led to superiority over so many other competitors is diminishing, and the utility of analytical cognitive activity is increasing because of the analytical demands of contemporary society.

The steady growth of analytical tasks is also reflected in the analytical bias of researchers studying judgment and decision processes. This bias is reflected by the present frequent use by researchers of artifactual materials and verbal and quantitative data cues, in contrast to the wholistic and spatial material and unlabelled, unmeasured cues, that naturalistic tasks provide for the right hemisphere.

Summary. Parallelisms between the work in judgment and decision research and research in the field of localization of brain function were noted and explored. It was concluded that further, detailed explorations of the conceptual similarities and empirical convergences is indeed warranted because of the mutual support and test that each field can provide for the other. In addition, this convergence leads to the observation that the properties of quasi-rationality are conducive to survival in naturalistic environments, that is, in environments that present (simultaneously) a large number of cues of uncertain ecological validity that afford a moderate amount of (horizontal) redundancy and other characteristics that induce cognition to move toward the intuitive pole of the cognitive continuum. Furthermore, because the mathematical-statistical representation of quasi-rationality is "robust," quasi-rational cognition is conducive to survival not only because of its fit with the naturalistic circumstances in which human beings evolved, but also because its robustness minimizes the need for learning, and thus provides an epistemological advantage. It was also noted, however, that the cognitive tasks constructed by contemporary human beings induce movement toward the analytical pole of the cognitive continuum, and are thus exerting cognitive demands that are different from those that selected quasi-rational organisms for survival. The increasing focus on analytical cognition may also be observed in the preference of researchers in judgment and decision research for using analytical models as reference points for the evaluation of cognition, and thus narrowing our view of cognitive activity.

SUMMARY

The five major premises of the Cognitive Continuum Theory of judgment and decision making were described and the potential power of the theory to encompass and to unify the work in the field of judgment and decision making was indicated. Because the theory is anchored in the concepts of intuitive and analytical cognition (see Premise 1), the recent treatment of these topics was described under Premise 2 in terms of the positive view, in which intuitive cognition is praised for its special capabilities to accomplish what analysis cannot, and in terms of the negative view, in which intuitive cognition is

denigrated for its failures, "shortcomings and distortions"; in short, its inability to accomplish what analysis can. In contrast to both views, it was argued that the Cognitive Continuum Theory put forth a "comprehensive view," for it provides a means for encompassing cognitive tasks, cognitive activities and their behavioral and adaptive consequences over the full range of cognition. This means examining the various properties of the many different cognitive tasks that are encountered by contemporary human beings, as well as examining the properties of the cognitive activities induced by such tasks and the adaptive consequences of the behavior that follows.

This effort was made in connection with Premise 3; various properties of cognitive tasks were listed, the various properties of cognitive activities that are associated with these task properties were listed, and predictions were made regarding the behavior that follows from various cognitive activities. The central role of time in all studies of cognition was deemed to be so important that it was given separate treatment under Premise 4. And the convergence of the major concepts of the Continuum Theory with the recent results of brain research that focuses on the lateralization of structure and function was discussed in connection with Premise 5.

Can it be said that the theory provided here meets Popper's (1963, p. 241) criteria for a unifying theory? Does it in fact "proceed from some simple, new, and powerful unifying idea about some connection or relation between hitherto unconnected things . . . or facts . . . or new 'theoretical entities'"? Whether the Cognitive Continuum Theory meets these criteria, the reader will have to judge;

but, of course, the author's view is that the theory is indeed simple and new; its power to find a relation between "hitherto unconnected things . . . or facts . . . or new theoretical entities" must be tested in terms of its ability to find places for the various results that have been attained in the field of judgment and decision research, but in terms of its ability to incorporate research on the localization of functions in the brain as well, and to apply them to a new field, evolutionary epistemology.

This report presents a new theoretical entity, the Cognitive Continuum; the ability of the Cognitive Continuum to find a "new relation between hitherto unconnected things . . . or facts" will be tested in subsequent Technical Reports.

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TABLE 1

COMPLEXITY OF TASK STRUCTURE

INDUCING INTUITION	INDUCING ANALYSIS
1. TEXTURE OF JUDGMENT SCALE	1. TEXTURE OF JUDGMENT SCALE
A. MANY ALTERNATIVES	A. FEW ALTERNATIVES
B. MANY STEPS TO SOLUTION	B. FEW STEPS
2. NUMBER OF CUES PRESENTED	2. NUMBER OF CUES PRESENTED
A. MANY (>5) CUES CONTEMPORANEOUSLY DISPLAYED	A. FEW (2-4) CUES SEQUENTIALLY ENCOUNTERED
3. VICARIOUS MEDIATION	3. VICARIOUS MEDIATION
A. INTRA-ECOLOGICAL CORRELATIONS PRESENT TO LARGE (R = .5) DEGREE (HORIZONTALLY)	A. INTRA-ECOLOGICAL CORRELATIONS MINIMAL (VERTICALLY)
4. CUE DISTRIBUTION CHARACTERISTICS	4. CUE DISTRIBUTION CHARACTERISTICS
A. NORMAL	A. PEAKED
B. LINEAR FUNCTION FORMS	B. NONLINEAR, NONMONOTONIC FUNCTION FORMS
5. WEIGHTS	5. WEIGHTS
A. EQUAL	A. UNEQUAL
6. ORGANIZING PRINCIPLE	6. ORGANIZING PRINCIPLE
A. LINEAR MODEL	A. NONLINEAR MODEL

TABLE 1 (CONTINUED)

AMBIGUITY OF TASK CONTENT

INDUCING INTUITION	INDUCING ANALYSIS
1. AVAILABILITY OF AN ORGANIZING PRINCIPLE	1. AVAILABILITY OF AN ORGANIZING PRINCIPLE
A. NOT AVAILABLE	A. READILY AVAILABLE
2. TASK OUTCOME AVAILABLE	2. TASK OUTCOME AVAILABLE
A. NOT AVAILABLE	A. READILY AVAILABLE
3. FAMILIARITY WITH CONTENT	3. FAMILIARITY WITH CONTENT
A. NOT FAMILIAR	A. HIGHLY FAMILIAR
4. FEEDFORWARD	4. FEEDFORWARD
A. NO TRAINING, NO INFORMATION	A. PRIOR SKILL, INFORMATION
5. FEEDBACK	5. FEEDBACK
A. MINIMAL	A. COGNITIVE FEEDBACK

FORM OF TASK PRESENTATION

INDUCING INTUITION	INDUCING ANALYSIS
1. TASK DECOMPOSITION	1. TASK DECOMPOSITION
A. A POSTERIORI	A. A PRIORI
2. COGNITIVE DECOMPOSITION	2. COGNITIVE DECOMPOSITION
A. A POSTERIORI	A. A PRIORI
3. TYPE OF CUE DATA	3. TYPE OF CUE DATA
A. CONTINUOUS	A. DICHOTOMOUS
4. TYPE OF CUE DEFINITION	4. TYPE OF CUE DEFINITION
A. PICTORIAL	A. QUANTITATIVE
B. SUBJECT MEASURES CUE LEVELS	B. OBJECTIVE MEASURES
5. RESPONSE TIME PERMITTED OR IMPLIED	5. RESPONSE TIME PERMITTED OR IMPLIED
A. BRIEF	A. OPEN

TABLE 2

PREDICTIONS OF COGNITIVE PROPERTIES IN SINGLE-SYSTEM CASE

INTUITIVE COGNITION	ANALYTICAL COGNITION
1. Low cognitive control	1. Opposite
2. Unconscious data processing, with regard to weights, function forms, organizing principles	2. Opposite
3. Vicarious functioning (includes shifting cue utilization)	3. Opposite
4. Rapid data processing	4. Opposite
5. Raw data or events stored in memory	5. Complex organizing principles stored in memory
6. Pictorial metaphors predominant; verbal, quantitative metaphors absent	6. Verbal, quantitative metaphors serve as organizing principles and hypotheses; pictorial metaphors absent (or appear only during intuitive phase of problem solving)
7. Right hemispheric activity predominant	7. Left hemispheric activity predominant
8. Stable policy means rigidity	8. Stable judgment subject to change with new information

TABLE 2A

LIST OF PREDICTIONS REGARDING PERFORMANCE IN SINGLE-SYSTEM CASE

1. INCONSISTENCY A. LOW PREDICTABILITY OF JUDGMENTS OVER TIME B. LOGICAL INCONSISTENCY (WHERE APPROPRIATE) C. FAILURE TO CONFORM TO MATH AXIOMS (WHERE APPROPRIATE)	1. OPPOSITE
2. LACK OF RETRACEABILITY OR AWARENESS OF PROCESS A. DIFFICULTY IN VERBALIZING B. EXPRESSING QUANTITATIVELY, COGNITIVE ACTIVITY	2. HIGH DEGREE OF RETRACEABILITY WHEN MOVING TOWARD SOLUTION; WHEN BLOCKED SUBJECT OFTEN RESORTS TO PICTORIAL REPRESENTATION OF THOUGHT, OR PICTORIAL ANALOGIES OR METAPHORS, THAT ARE RECOVERED
3. BRIEF RESPONSE TIME A. OTHER INDICATIONS OF ABSENCE OF ANALYSIS	3. OPPOSITE
4. LOW CONFIDENCE IN JUDGMENTS	4. OPPOSITE
5. CHANGE A. CHANGE IN COGNITIVE SYSTEM LIMITED TO CHANGE IN CUE WEIGHTS AS POLICY FORMED	5. CHANGE A. CHANGE IN WEIGHTS, FUNCTION FORMS AND ORGANIZING PRINCIPLES UNTIL STABLE POLICY REACHED B. RAPID CHANGE OCCURS WITH NEW INFORMATION
6. EQUAL WEIGHTING OF CUES OVER LONG TERM (I.E., "MATCHING" RATHER THAN "MAXIMIZING" BEHAVIOR)	6. OPPOSITE; WEIGHT CONCEPT NOT APPLICABLE
7. LINEAR FUNCTION FORMS	7. OPPOSITE
8. WEIGHTED AVERAGING ORGANIZING PRINCIPLE (COMPROMISE). NOTE: MATCHING HERE ALSO	8. ANY ORGANIZING PRINCIPLE (OTHER THAN WEIGHTED AVERAGING POSSIBLE)
9. EVENT MEMORY	9. MEMORY OF PRINCIPLES (INCLUDING METAPHORS IN CREATIVE PHASES)
10. RIGHT SIDE BRAIN ACTIVITY	10. OPPOSITE

TABLE 3

PREDICTIONS OF COGNITIVE PROPERTIES IN DOUBLE-SYSTEM CASE

INTUITIVE COGNITION	ANALYTICAL COGNITION
1. Low cognitive control	1. Opposite
2. Unconscious data processing with regard to weights, feedforward, organizing principles	2. Opposite
3. Vicarious functioning (includes shifting cue utilization)	3. Opposite
4. Rapid data processing	4. Opposite
5. Raw data or events stored in memory	5. Complex organizing principles stored in memory
6. Pictorial metaphors predominant; verbal, quantitative metaphors absent	6. Verbal, quantitative metaphors serve as organizing principles and hypotheses; pictorial metaphors absent (or appear only during intuitive phase of problem solving)
7. Right hemispheric activity predominant	7. Left hemispheric activity predominant
8. Stable policy means rigidity	8. Stable judgment subject to change with new information

TABLE 3A

PREDICTIONS OF ACHIEVEMENT FOR DOUBLE-SYSTEM CASE

(NOTE: PREDICTIONS OF PERFORMANCE FROM SINGLE-SYSTEM CASE CARRY FORWARD.)

INTUITIVE COGNITION	ANALYTICAL COGNITION
1. SLOW, 'STUPID' LEARNING FROM INEXACT (PROBABILISTIC) OUTCOMES; E.G., LARGE NUMBER OF TRIALS TO SOLUTION	1. OPPOSITE
2. NORMAL DISTRIBUTION OF TASK ERRORS	2. NON-NORMAL DISTRIBUTION OF ERRORS
3. 'STEREOTYPED,' PERSISTENT USE OF CUES	3. OPPOSITE
4. FREQUENT APPEAL TO EVENT MEMORY FOR RECALL OF TASK PROPERTIES AND PERFORMANCE	4. FREQUENT APPEAL TO ORGANIZING PRINCIPLE FOR RECALL OF TASK PROPERTIES AND PERFORMANCE
5. TRANSFER LOW; TASKS WITH DIFFERENT CONTENT	5. TRANSFER HIGH OVER DIFFERING CONTENT
6. UNDERCONFIDENCE (CONTRAST BETWEEN OBSERVED PERFORMANCE AND REPORT OF CONFIDENCE)	6. OPPOSITE
7. INCONSISTENCY MATCHES TASK UNPREDICTABILITY OVER OCCASIONS	7. INCONSISTENCY FROM TRIAL TO TRIAL; NOT MATCHED TO TASK; MAXIMIZING STRATEGY IN TASKS PROVEN TO BE STOCHASTIC

Figure Caption

Figure 1. Darwin's first three tree diagrams on pages 26 and 36 of the First Notebook (from Gruber, H. E., Darwin's "tree of nature" and other images of wide scope. In J. Wechsler (Ed.), On aesthetics in science. Cambridge, MA: MIT Press, 1979.).

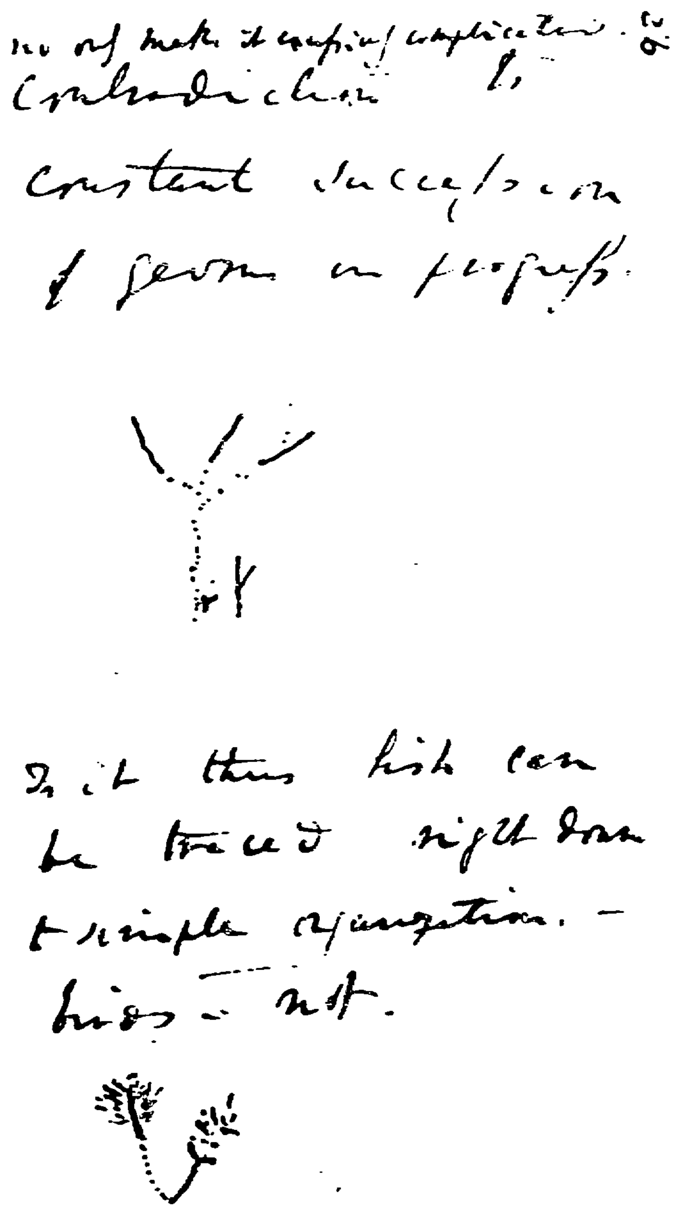

Figure 1. Darwin's first two tree diagrams, on page 26 of the *First Notebook*. Immediately preceding the upper tree the MS reads, "The tree of life should perhaps be called the coral of life, base of branches dead; so that passages cannot be seen.—[end of p. 25, beginning of p. 26] this again offers ((no only makes it excessively complicated)) contradiction to constant succession of germs in progress." Words in double parentheses were inserted above the line by Darwin.

Immediately preceding the lower tree the MS reads, "Is it thus fish can be traced right down to simple organization—birds—not." Courtesy of

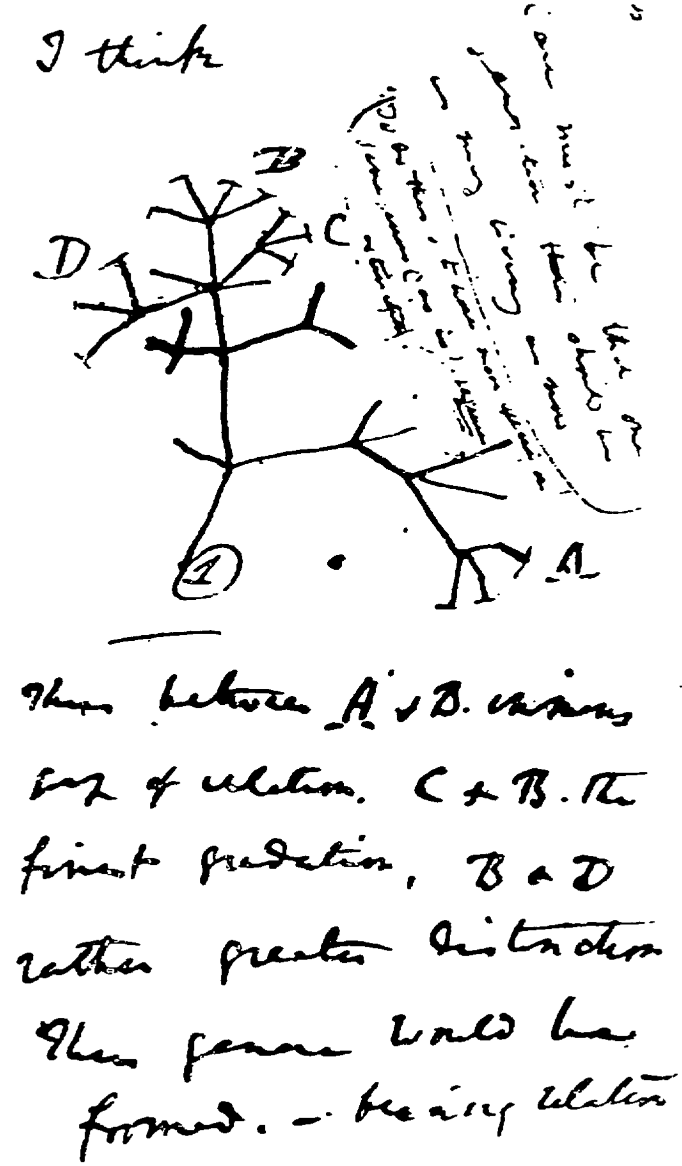

Figure 2. Darwin's third tree diagram, on page 36 of the *First Notebook*. The MS reads, "I think" followed by the diagram. Then, "Thus between A & B immense gap of relation. C & B, the finest gradation, B & D rather greater distinction. Thus genera would be formed,—bearing relation [end of p. 36, beginning of p. 37] to ancient types." The marginal insertion alongside the tree diagram reads, "Case must be that one generation then should have as many living as now. To do this & to have many species in same genus (as is), requires extinction." Courtesy of the Syndics of Cambridge University Library.

120

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