CLINICAL INTUITION AND CLINICAL ANALYSIS: EXPERTISE AND THE COGNITIVE CONTINUUM.

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1 Overview.

This paper addresses medical students' and clinicians' concerns about how to reason well. It describes the many kinds of thinking people can do successfully, ranging from very intuitive cognition to the very analytical. Two theories of intuitive and analytical cognition, by Kenneth Hammond and by Hubert and Stuart Dreyfus, are discussed. It will be shown that: The kind of task that a doctor is working on has an important role in determining the kind of thinking that is likely to be used. The match between the task characteristics and the kind of thinking influences the accuracy of the thinking. The extent of the doctor's experience also influences the kind of thinking used and its likely success.

2 Introduction.

At some point in their medical training, most likely near the time when they first take responsibility for patient care, most doctors develop an intense interest in thinking -- How should one *think* to discover the cause of a patient's 3-day fever? Given an uncertain diagnosis, and available treatments that "usually work" but that have painful side effects, how should one *think* when deciding on a treatment plan?

It is natural that clinical decision makers should try to copy the thinking of the experts. This is especially true for medical students: seeking to think correctly about their first patients, they look for guidance to the experienced doctors who teach in medical schools. But these experts offer a number of different models:

1. When presenting case histories in their lectures, professors show reasoning that is elegantly logical in its use of science in the diagnosis of hidden diseases and the selection of correct treatments.
2. On teaching rounds, the clinical professors lead the medical students and residents in a systematic consideration of all the evidence about the patient, yet they use their own perceptions and judgments, justified by reference to informal rules of thumb, to guide the diagnostic conclusions and treatment decisions.
3. When an expert clinician sees a patient, without explaining things to students, it is not evident that any "reasoning" is being used at all. The clinician seems to know what to do after a few questions.

The thinking processes that expert clinicians reveal in these three contexts are very different.

While it may take 20 minutes of teaching rounds for the doctor and students to arrive at a tentative diagnosis, experienced clinicians typically formulate initial hypotheses within 15 seconds of talking with a new patient (Elstein et al, 1978). Computer scientist William Clancey discovered the vast differences in experts' reasoning processes, when he sought to modify MYCIN, an "expert system" program that mimics how specialists diagnose meningitis, so that it could tutor students with the teaching style of one of the specialists. To make an expert system, a computer scientist will as an expert (or experts) to explain how he or she reasons, and encode the explanations as rules in the computer program. The reasoning that Clancey's expert revealed when modeling tutoring to help produce an expert tutoring program was so different from the reasoning that a team of experts revealed when modeling diagnosis for the expert diagnosing program that it was necessary to rewrite the knowledge in the program extensively before it could be used for teaching (Clancey, 1983). Clancey's situation is analogous to that of the medical student seeking to model his or her own thinking after an expert clinician's thinking. The medical student will find that the expert's thinking processes in different situations seem to be completely incompatible. Which process (if any) should the student emulate?

Faced with such an impass, the medical student, or indeed anyone interested in improving clinical judgment and decision making, might wish to consult psychology or cognitive science to see what scientists have to say about expert thinking. Perhaps researchers in these fields have discovered how experts really think, and can tell relatively inexperienced clinicians the best way to reason about diagnoses and decisions, even if the expert clinicians have no perspective on their own cognitive processes. There has in fact been extensive study of expert reasoning on diagnosis, problem solving, and decision making tasks (Chi and Glaser, 1984; Ericsson and Simon, 1984; Greeno and Simon, 1984; Hammond, McClelland, and Mumpower, 1980; Kahneman, Slovic, and Tversky, 1982), including tasks in the domain of medicine (Elstein, Rovner, Holzman, et al, 1982; Elstein, Shulman, and Sprafka, 1978; Johnson, 1982; Neame et al, 1985; Wigton, Hoellerich, and Patil, 1986).

Most psychologists and cognitive scientists assume that thinkers receive perceptual inputs about their situation (e.g., by looking at and listening to the patient, by reading test results); interpret these inputs according to categories of knowledge that reside in memory, thus producing a representation of the situation (Rouse and Morris, 1986); consider how to use their skills to attain their goals in the represented situation; modify their representations as they get new information or gain new insight; produce, evaluate, and select plans of action; and finally carry out those plans. But there is considerable disagreement about how these various steps <u>are</u> done and <u>should</u> be done, about what aspects of the process change as one becomes more expert, and about which of these steps are most essential for accurate thinking. For example, it is generally acknowledged that people are capable of applying rules to the inputs to guide their categorizations and actions. It is also acknowledged that they are capable of perceiving and acting without explicitly applying rules. But researchers disagree about whether such rules are essential for accurate performance, or actually impede it. The clinician who has gone to the research literature for insight should keep in mind that thinking needs to be understood in context. The two important contexts to be covered here are the <u>task</u> and the thinker's <u>expertise</u>.

These contexts will be framed in terms of the important distinction between analytical and intuitive cognition, which can help a doctor understand how to think well in different medical contexts and at different stages in one's learning of medicine. The paper draws on the theoretical and empirical contributions of Kenneth Hammond, a psychologist whose Cognitive Continuum Theory describes analysis and intuition as distinct kinds of thinking, and shows how cognition depends on task characteristics (Hammond, 1980, 1981, 1986b). It also covers the theory of philosopher Hubert Dreyfus and operations researcher Stuart Dreyfus, who have characterized the development of expertise in terms of changes in the use of analytical and intuitive thinking (Dreyfus and Dreyfus, 1986).

In the perspective of these theorists, certain questions become sensible that are not commonly asked in psychological and cognitive science research, questions that are directly pertinent to the predicament of the medical student or clinician seeking guidance about how to think well:

1. What kinds of thinking, analytical or intuitive (or a mixture), should be used in various medical situations?
2. How does the practitioner discover or decide which mode of cognition to use?
3. How can the appropriate kind of thinking be performed as well as possible?

The clinician reading the research literature will need to keep this perspective in mind in order not to be discouraged by the apparent irrelevance of much research to his or her present problems. It is not that research is "too abstract" or "about unrealistically simple tasks." The problem, rather, is that researchers themselves lack perspective on the full range of kinds of thinking that people can do (Hammond, 1986b). Although Cognitive Continuum Theory (Hammond, 1980, 1983, 1986b) can serve as a framework for describing the many tasks that people are capable of performing, and the many kinds of thinking ("modes of cognition") that they can employ on these tasks, most researchers in psychology and cognitive science have chosen to situate their work within more limited horizons. While this narrow focus enables them to make progress in understanding the way people think on the particular tasks the researchers are studying, it also leads them to make exaggerated claims about the generality of their findings (Hammond, 1986a). The medical student or clinician seeking guidance in "how to think" is likely to reject the entire psychological research endeavor upon reading advice based on research on a task that is quite different from the current case.

3 A Framework for Placing Cognition in Context.

Because the Cognitive Continuum is a framework in which different kinds of thinking and different kinds of task can be placed, it can provide structure for advice about how one can improve one's thinking on various tasks. The elements of this framework are: a range of kinds of cognition, a range of task conditions, and a range of modes of practice (Hammond, 1978, 1980, 1981).

3.1 The Cognitive Continuum.

The venerable distinction between analysis and intuition has stimulated little research because intuition has been defined only as "the absence of analysis". Hammond (1980) sought instead to define the intuitive pole of the cognitive continuum in terms of specific features: Intuitive thought involves rapid, unconscious data processing that combines the available information by "averaging" it, has low consistency, and is moderately accurate. The expert clinician seeing a patient in the office, as described above, is using intuitive cognition. Analysis, the other end of the cognitive continuum, has the opposite features: Analytic thought is slow, conscious, and consistent; it is usually quite accurate (though it occasionally produces large errors); and it is quite likely to combine information using organizing principles that are more complicated than simple "averaging". The professor's lecture exemplifies analytical reasoning about a case. In its claim that intuition involves the combination of cues by the simplest psychological process, averaging, Cognitive Continuum Theory goes against the argument that experts make "configural" use of information in their clinical judgments (see Dawes, 1979; Goldberg, 1970; and Holt, 1970).

Analytical and intuitive thinking are defined as poles of a "continuum" because most thinking is neither purely intuitive nor purely analytical, but rather lies somewhere in between. This "in between" or "quasirational" cognition can have intermediate values on the features (e.g., it could take a moderate amount of time), or it can have a mixture of features (some features that are characteristic of analysis and others that are characteristic of intuition), or finally, it can involve alternation back and forth between analysis and intuition (Hammond, 1981; Hamm, 1985). The reasoning of the clinical professor leading students on teaching rounds exemplifies this quasirational cognition.

As an exercise, the reader may compare doctors' or students' reasoning, in situations he or she has observed, with the features listed above in order to place it on the cognitive continuum.

3.2 The Task Continuum, and the Influence of Task on Cognition.

Knowing that there are different kinds of thinking does not tell one which kind to use. For a clinician to convert the notion of a cognitive continuum, ranging from analysis to intuition, into guidance about how to think, two other ideas central to Hammond's theory are pertinent:

1. The doctor's task induces him or her to select a corresponding mode of cognition. Thus, some cases will induce a physician to think about them analytically, others will elicit intuitive cognition. The pertinent task features are reviewed in the remainder of Section 3.2.
2. The accuracy of cognition depends in part on whether the doctor selects the appropriate mode of cognition. If a physician tries to take an intuitive approach to a case which induces analysis, or vice versa, it will be difficult to reason accurately. The relation between task and accuracy is discussed in Section 3.3.

The first idea gives a basis for understanding why we would see an expert clinician thinking analytically in one situation and intuitively in another. The second idea gives grounds for evaluating whether someone's thinking is appropriate for the task. Section 3.4 covers the use of these ideas in combination to guide one's thinking.

In Cognitive Continuum Theory, tasks are considered to occupy a position on a task continuum, ranging from analyis-inducing to intuition-inducing, indicated by task features that influence the mode of cognition that the thinker will adopt. These features include the complexity of the task, the ambiguity of the content of the task, and the form of task presentation. The following are examples of features in each category (Hammond, 1980, 1981, 1986b).

1. Complexity of task structure.

a. Number of cues -- the more pertinent cues there are, the more likely the task will induce intuition. Given much information about a case, the doctor will probably use intuition to make the diagnosis.

b. Redundancy of cues. The more the cues can be predicted from each other, the more likely intuitive cognition will be used.

c. Identity of the accurate organizing principle. If a simple linear weighted average organizing principle is known to be most accurate, this is likely to encourage the doctor to use intuition. If, on the other hand, it is known that a complicated procedure for combining the evidence is most likely to produce an accurate answer, then a clinician would be likely to reason analytically about such a situation.

2. Ambiguity of task content.

a. Availability of the organizing principle. If a complex organizing principle is readily available, the doctor is likely to use it, hence to be analytical.

b. Familiarity of the task content. Unfamiliarity induces an intuitive approach, involving the averaging of available cues, due to the unavailability of more complicated principles for organizing the cue information (Hammond, 1980, pp 60-63; see Section 6.2, below).

c. The possibility of high accuracy. If the doctor knows that it is possible to be highly accurate on a particular diagnostic or treatment selection task, he or she is likely to use analysis.

3. Form of task presentation.

a. Task decomposition. If the task is presented in a manner that guides the doctor to address a sequence of subtasks, this will induce analytical cognition.

b. Cue definition (manner of presentation of information). If the information is presented pictorially, it induces intuition. If the cues are measured objectively and presented to the doctor in a quantitative form, it induces analysis.

c. The permitted or implied response time. If only a brief time is available, the doctor will adopt intuitive cognition. For example, a doctor with 20 patients scheduled for three hours in the clinic knows that intuition is the mode the institution expects.

Hammond, Hamm, Grassia, and Pearson (1984) varied these task features to determine their effect on expert highway engineers' modes of cognition. The task conditions were varied along two independent dimensions -- "deep" and "surface" task features. The "deep" task feature bundles varied the content of the task and the degree of nonlinearity of the optimal organizing principle (among other features). The "surface" task feature bundles varied the mode of presentation of information, the number of cues, and the cue redundancy (among other features). It was found, as Cognitive Continuum Theory predicted, that both deep and surface task features had significant effects on the mode of cognition.

The social and institutional context can also be expected to have a role in determining the mode of cognition a doctor uses (Hamm, Clark, and Bursztajn, 1984). Much medical reasoning, particularly in hospital settings, takes place in discussions involving people with different fields of training, different experience, and responsibility for different aspects of the patient's treatment (Climo, 1984). Such a group of people will readily accept some kinds of thinking from a doctor -- that which is familiar, that which seems competent, that which seems to eliminate uncertainty (Bursztajn, Feinbloom, Hamm, and Brodsky, 1981). However, the group may not accept highly analytical thinking if they do not understand it. And they may reject intuitive thinking on the part of a junior physician if it can not be justified with reasoning that is more analytical.

The institution too affects the prevailing mode of cognition used in diagnosis and decision making, through the kind of staff training it provides or pays for, the amount of time it allows for reasoning about each patient, the kind of information that is routinely made available (e.g., tests, records, literature), the accessible tools (e.g., computers, software), and the rewards and punishments that are contingent on patient outcomes or physician practices. The medical student will need to be sensitive to the effects of such social and institutional factors on his or her thinking, as well as on others' thinking -- even the thinking of doctors with greater experience.

No one task feature or contextual factor can completely determine a doctor's mode of cognition. For example, even when information is presented pictorially (as with chest X-rays), the doctor may know that high accuracy is possible, and hence reason analytically.

The ability of a task feature to induce a mode of cognition depends also on what the thinker knows. If one does not know that there is a generally accepted procedure for analyzing lung capacity, then that "task feature" can not make one think analytically in interpreting lung capacity data. For an illustration of this, consider a study of a formal tutorial conversation between a medical student and a teacher, where it was observed that the teacher thought more analytically. In this unpublished study (done in 1985 by Hamm, Hammond, and Grassia; methodology described by Hamm, 1985), the medical student presented a case to the teacher, and then they discussed it as they would on rounds. All statements were coded in terms of their degree of analysis. The teacher was consistently more analytical than the student throughout the whole conversation. Even though both were thinking about the same case, the greater knowledge of the teacher enabled him to think about it and explain it more analytically.

3.3 The Relation of Cognition/Task Correspondence and Accuracy.

Hammond (1980, 1981) argued that people's reasoning is relatively more effective when the mode of thinking they adopt corresponds to the task features. For example, if all the conditions of a case demand analytical cognition but the doctor tries to handle it intuitively, errors can be expected. On the other hand, if the information presentation, the problem context, and the social environment induce intuition, but the doctor tries to use an analytical approach, poor performance can again be anticipated. Empirical evidence for this relationship was found by Hammond, Hamm, Grassia, and Pearson (1984), who measured the extent to which their engineer subjects' cognition (when judging the capacity, safety, and aesthetic value of highways) corresponded to the task features, and found, in a within subject analysis, that the closer the correspondence, the greater the engineers' accuracy.

Clinicians, starting in their medical student days, are therefore advised to learn to identify and control the kind of thinking they are using, and to attend to those characteristics of their situation that would induce analysis or intuition. They can use this awareness to choose appropriate modes of cognition to use on their professional tasks, thus influencing their accuracy on the tasks.

3.4 The Six Modes of Practice.

The ideas presented above will be helpful to the clinician but they do not exploit the full power of Cognitive Continuum Theory to provide a basis for a systematic approach to improving the accuracy of one's thinking. The *induction* idea, that features of the doctor's task induce the mode of cognition he or she will use, is helpful because it explains why we see experts thinking differently in different situations. The notion that *correspondence between cognition and task features partially determines accuracy* is also helpful, for it can guide adjustments that one might make to one's cognition, or to the task, to improve the accuracy of one's reasoning. To understand the next possible step, consider this question: If it were possible to have cognition and task be well-matched at any position along the cognitive continuum, at which position would the most accurate reasoning take place? It is plausible that for every patient, there is an ideal task-cognition combination. That is, the doctor's reasoning might be most accurate if the approach to the patient's problem were formulated as a task at a particular position on the task continuum and the cognition were at the corresponding position on the cognitive continuum. Let us use the term "practice" to refer to both the characteristics of the task and the cognition the doctor uses on that task. To rephrase the question, what is the ideal mode of practice for a particular patient?

To make this conception usable, the doctor must have control not only over his or her cognition but also over the task features. Our discussion so far has assumed the doctor is a reactive thinker, who selects a kind of thinking in response to the given (externally controlled) task features. We also imagined the doctor trying out one mode of cognition in a number of situations that have different task features. But we should recognize that people have the ability to change the features of the tasks that face them (Basseches, 1984; Riegel, 1978, 1979). Indeed, it may be easier to control the task features and let them drive the selection of cognitive mode, than to simply "will" a change in cognitive mode. This is analogous to Skinner's (1953) observation that it is easier to change the contingencies of reinforcement and let them drive the behavior, than to directly "will" a change in behavior. Thus it is sensible to speak of shifting the features of a particular task, and the cognition one uses on it, until the most accurate position on the continuum of possible modes of practice is found.

In a study by Hammond, Hamm, Grassia, and Pearson (1984), the accuracy of highway experts judging the capacity, safety, and aesthetic value of highways was measured, using three presentation modes (the bundles of surface task features mentioned above) for each judgment task. In each judgment task, the more analytical modes of practice were more accurate. That is, the presentation mode with the more analytical task features (and the corresponding cognition) produced the more accurate judgments. This advantage of analysis would not necessarily be found with other kinds of task content; the point here is the possibility of performing better on a task after changing the task features and the corresponding cognition together.

Hammond (1978) divided the task/cognition continuum into six modes of inquiry. The first, most analytical, mode occurs in the laboratory of the hard sciences (physics, chemistry). The sixth, most intuitive, mode occurs wherever an individual judge is operating with minimal support from colleagues or reference to impersonal aids (e.g., a doctor on a home visit). The more analytical the mode of cognition and the more structured the task, (a) the greater the possibility of variable manipulation by the judge in the judging process; (b) the greater the visibility of the judgment process (i.e., openness to inspection or replication by others); and (c) the greater the time (and usually resources) required by the process (see Figure 1). This framework has been applied to the problems of medical diagnosis (Hammond, Hamm, Fisch, and Joyce, 1982) and medical decision making (Hamm, Clark, and Bursztajn, 1984). As these applications cover the general problems of correct knowledge and correct action, respectively, I will speak of 'modes of practice' rather than 'modes of inquiry', with the former term encompassing the latter.

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Insert Figure 1 about here.

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Correct Knowledge: Epistemological Safeguards. Doctors value accurate diagnoses. Different reasoning strategies are used to assure the quality of their causal reasoning, in each of the modes of practice (see Table 1). The safeguard used in Mode 1, the most analytical mode, is highly controlled experimentation. The safeguard in Mode 6 is nothing more than an individual's opinion justified by the authority of his or her experience. Table 1 (modified from Hammond, Hamm, Fisch, and Joyce, 1982) distinguishes among the modes by reference to the epistemological safeguards that can be used in each mode. It lists features whose presence or absence characterizes these safeguards. While the usual conditions for the acquisition of medical knowledge involve epistemological safeguards at Modes 1, 2, and 3, the usual conditions for its application in the clinic involve Modes 6 (uncriticized, private judgments), and 5 (group discussion), and on rare occasions, Mode 4 (for example, using cognitive aids such as Bayes' Theorem with subjectively assessed probabilities; see Weinstein et al, 1980).

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Insert Table 1 about here.

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Correct Action: Decision Making. Doctors wish to make decisions optimally. The feasible methods for selecting the treatment plans that have the best expected utility for the patient are different for each mode of practice. Table 2 (modified from Hamm, Clark, and Bursztajn, 1984) shows the methods that can be used to select the best decision in each of the six modes of practice, and lists features whose presence or absence distinguishes among these methods. Modes 6 and 5 are most commonly encountered in the clinic (see Climo, 1984; Hamm, Clark, and Bursztajn, 1984). Modes 1 through 4 involve the use of a formal decision analytical framework, including the measurement of the probabilities and utilities. If the probabilities and utilities are subjectively estimated, it would be Mode 4 cognition; if the probabilities can be measured with reference to the relative frequencies of events in a large data base, and the utilities can be measured by systematically surveying a large number of people, it would be typical of Mode 3.

Analyses of this sort are frequently published in the journal Medical Decision Making (e.g., Matchar and Pauker, 1986).

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Insert Table 2 about here.
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Inspection of the descriptions of the modes of practice in Tables 1 and 2 should convince the reader that a doctor does not have the option of choosing a mode at will for a given situation. The medical "state of the art", as well as the social and institutional factors which provide the context for the doctor's thinking and acting, can not be so easily changed that every mode of practice can be applied (Bursztajn, Feinbloom, Hamm, and Brodsky, 1981). For example, in my freshman physics laboratory, the assignment was to measure a distance marked on the floor, without laying a yardstick along it. This is a Mode 1 or 2 problem. One classmate's solution was to poll the others and average their guesses. This Mode 4 solution was not acceptable in that context, as his lab partner quickly let him know. And along with that situational unacceptability, in fact driving it, was the fact that the answer produced by this method was much less accurate than the more analytic methods' answers. Similarly, for any particular medical problem, the doctor will not have the whole range of modes of cognitive practice as options. But yet there will be options within a narrow range (cf Adelman, Sticha, and Donnell, 1984). The choice among those options is what we consider next.

Selection of a Mode of Practice. Consider a medical situation where the doctor has the choice of reasoning at the level of Mode 5 (arriving at a treatment plan through discussing the options with peers, justifying and criticizing each option in turn until a consensus plan is reached) or reasoning at Mode 4 (through applying the decision analytic framework to the options and their potential outcomes, getting subjective estimates of the probabilities that the outcomes would follow each option, plus subjective assessments of the utility of each outcome, and combining these (by a weighted sum, weighting the outcomes' utilities by the probabilities that they would occur) to find the expected value of each option). There is a very obvious tradeoff here, between (a) the more analytic Mode 4 procedure which (1) promises higher accuracy but (2) requires more effort to do and to convince others to accept, and (b) the more intuitive Mode 5 procedure which, while (1) easier, (2) involves knowledge and actions in which one has less confidence (Hammond and Hamm, 1983). This is not an easy choice, and the difficulty does not go away once one has earned one's medical degree.

Doctors' decisions about which mode of practice to use are not as wise as they could be, because the tools that can help them reason well at each mode are not well known. Let us consider two types of tools -- tools which help bring the normative perspective to bear, and tools which "capture" or make public the doctors' judgment policies so that they can be inspected, compared, or combined.

Normative Tools. The general norms for diagnostic reasoning are exemplified by Bayes' Theorem and ROC analysis. The general norm for decision making is decision theory, applied as outlined in the example two paragraphs above (see Table 2). Formal application of these norms requires cognition at least as analytical as Mode 4. Many doctors may not know that techniques for applying these norms with subjective judgments (Mode 4) are available; some who do may exaggerate the valid criticisms that have been made of these techniques (cf Bursztajn and Hamm, 1982; Feinstein, 1977); and some who respect the approaches in principle may not know how to use them. These factors, rather than a fair evaluation of the advantages and disadvantages of using these normative procedures at Mode 4, may be what causes a doctor to practice at Mode 5 with a particular patient. This is a lost opportunity that could perhaps be recovered through education and advocacy (Lusted, 1984).

But the formal application of Bayes' Theorem or an expected utility formula is not the only way to bring these norms to bear on one's practice. Accurate use of the language of probability, phrased perhaps in the everyday terms of gambling (Bursztajn, Feinbloom, Hamm, and Brodsky, 1981), can keep the normative perspective in mind in discussions at Mode 5 of practice. Using such a conceptual framework accurately is not easy, and requires study of concepts, as well as monitoring of practice for accuracy. Opportunities may be lost if the doctor does not know how to use this informal normative reasoning tool, whether the loss be because the doctor practices at Mode 5 without the aid of probabilistic language, or because the doctor shifts to Mode 4 in the belief that the norm can not be respected at Mode 5, when in fact the formal normative tools are infeasible for the particular case.

A similar dilemma is found where medicine interfaces with the law, i.e., in the realm of medical malpractice arguments. Courts have recognized three types of justification -- the intuitive "community standards", in which a doctor who does what other doctors do is not negligent (Mode 6); the analytical "Learned Hand rule" which involves evaluating the doctor's practice against an expected value criterion (Mode 3 or 4); and the intermediate "reasonable and prudent person" standard, which involves determining whether the doctor did what a careful thinker would have done in the circumstances -- which is presumably to apply flexible, context-sensitive, critical reasoning to the problem (Mode 5), recognizing the issues addressed by the more formal decision analysis without being bound to its methods (Bursztajn, Hamm, Gutheil, and Brodsky, 1984).

Tools of Judgment Analysis. Appropriate methods from cognitive psychology can be used at each mode of cognition to describe the doctor's thinking. Such descriptions can be useful in a number of ways. Let us consider applications of these methods at Modes 6, 5, and 4.

Mode 6. A doctor making uncriticized decisions in social isolation (Mode 6) could be given "cognitive feedback" -- could be presented with an objective description of his or her judgment policy, that is, a description of the way the given information is used in producing a decision (Hammond and Boyle, 1971). This description could be compared with the doctor's own conception of how he or she makes those judgments. If there were a standard governing this kind of judgment, the doctor's judgment policy could also be compared with this standard. Either way, the cognitive feedback would give the doctor insight that might lead to changes, so that the doctor's future judgments, although still made intuitively in a Mode 6 context, would be more accurate.

Mode 5. Doctors whose reasoning involves public justification and mutual criticism of courses of action use their own judgments as inputs to the group discussion. Judgment analysis techniques can clarify for group members the source of these inputs. Techniques for describing individuals' judgment policies have been used to call attention to the fact that specialists in rheumatoid arthritis have widely varying policies (Kirwan et al, 1983), which was not otherwise known. These techniques have also been used to show that disagreeing group members in fact have very similar basic judgment policies. Such objective descriptions of doctors' judgment policies could improve the accuracy of the group's thinking and the efficacy of the group's functioning without changing the group's basic mode of practice.

Mode 4. The tools of judgment analysis have also been useful at more analytical modes of practice. Hammond, Sutherland, Anderson, and Marvin (1984) worked with a group of experts who had widely divergent opinions on a particular case (the health danger of a nuclear weapons manufacturing facility located just outside of Denver). This group was led to focus on their subjective models of the causal relations among variables (instead of on the case), and they were able to agree on a causal model of the health effects of exposure to plutonium dust that applied to the particular case upon which they had previously disagreed. This example involves Mode 4 reasoning, because people discussed their subjective models of the relations among variables, and also Mode 3 reasoning, because when members of the group challenged each other they were asked to use epidemiological evidence to support their beliefs.

4 Evaluation of Cognitive Continuum Theory.

It has been demonstrated that Cognitive Continuum Theory's formalization of the age-old distinction between intuition and analysis can help the medical student or clinician (a) recognize the kinds of cognition, and the kinds of task that typically elicit them; (b) adjust his or her cognition so that it corresponds to the task, in the hope of increasing its accuracy; (c) change the task characteristics for a given patient to facilitate the form of cognition that is most likely to produce accurate answers for the patient; and finally (d) select appropriate techniques for applying a normative perspective to the case.

The theory provides a general framework, not specific instructions. It does not tell the student exactly how to think intuitively or analytically. Rather than explaining cognition and its relation to the task in terms of internal psychological processes and how these are controlled by task features, the theory describes features of the cognition and how these are correlated with task features. The student is oriented toward both the characteristics of the task and the kind of cognition he or she is using on the task, but is left the difficult jobs of assessing the situation, assessing his or her own capabilities, and deciding whether cognition or task must be changed.

Some doctors might hesitate to be guided by Cognitive Continuum theory because they think it overly simple to explain the various kinds of cognition in terms of just one basic dimension, the analytic/intuitive continuum. In the theory, any number of combinations of task features are said to produce cognition that is at the same point on the cognitive continuum. Thus, if the doctor can look at the patient (intuition inducing) but also knows of an appropriate principle for diagnosing the cause of this type of illness (analysis inducing), cognition at an intermediate point on the continuum would be expected -- but cognition at that same point could also be induced if the doctor did not actually see the patient but rather was given numerically measured information about him (analysis inducing) but knew of no appropriate diagnostic principle for this type of illness (intuition inducing). One might think that the reasoning in these two situations would be quite different, but Cognitive Continuum theory would make no further distinctions between them if they have the same position on the continuum (measured, for example, by the Cognitive Continuum Index developed by Hammond, Hamm, Grassia, and Pearson, 1984).

5 The Dreyfuses' Theory of Expertise.

The doctor who finds the cognitive continuum too simple may be more pleased with Dreyfus and Dreyfus' theory of expert cognition (1986). Where Hammond (1980, 1981) would place a doctor's cognition at one particular position on the continuum, Dreyfus and Dreyfus (1986) describe several levels of thinking involved in a task. Different modes of cognition can be used at each level. This idea of a structured task description has not figured prominently in the core of Cognitive Continuum theory (Hammond, 1980, 1981, 1986b), though Hamm (1985) looked for different modes of cognition on different subtasks of a complicated judgment task.

Dreyfus and Dreyfus describe five stages that one must go through to become, say, an expert physician -- novice, advanced beginner, competent, proficient, and expert. Performance at each stage involves these subtasks:

1. At the level of the whole situation, the doctor must be oriented and act.
   a. Orientation. The doctor must understand the facts and the motivating issues in the situation, e.g., he or she must recognize when a patient is an emergency.
   b. Decision. The doctor must formulate goals and plan coordinated actions to reach those goals.
2. At the level of the components of the situation, the doctor must perform a large repertoire of skilled actions.
   a. Perception. The doctor must recognize the relevant aspects of the situation, e.g., recognize signs of various illnesses in every part of the body.
   b. Action. The doctor must know what use to make of these perceptions -- what diagnoses to make, what further questions to ask or tests to order, what actions to take.

Like Hammond, the Dreyfuses consider analysis and intuition key in understanding people's cognition. Specifically, each of the above activities can be done intuitively or analytically (see Table 3). (While Dreyfus and Dreyfus use different phrases to describe the special characteristics of the analytical and intuitive thinking at each level, I will speak of only "analysis" and "intuition" here, to emphasize the structure of the theory.) The developmental stages are distinguished by those subprocesses of thinking which are handled analytically or intuitively at each stage. The novice must think analytically in order to perform, that is, must relate the present situation to guiding principles, consciously interpret sense perceptions, and follow rules about what to do if a particular sign is observed. For example, the medical student first learning to listen to the lungs does not know what to make of the sounds he or she hears, and is taught rules relating commonly known sounds to the needed perceptual categories -- E.g., "The fine crepitant rale is best imitated by moistening the thumb and finger tip, pressing them tightly together and them separating them while they are held near the ear" (Hare, 1902, p. 274), as well as rules relating *rales* to various lung conditions. The novice leaves the definition of the "whole situation" to the teacher. The advanced beginner has learned to perceive intuitively, e.g., can instantly distinguish "fine crepitant rales" from "fine bubbling rales", but must still apply rules to know what diseases these indicate. The competent doctor exercises both perception and action components of the skill intuitively, e.g., listens to lungs and hears the patient's condition. However, the competent doctor must still think analytically about the whole situation. The proficient doctor perceives the whole situation intuitively -- the important details stand out, others recede into the background -- but makes decisions analytically about the strategy for managing the patient. Finally, the expert makes these decisions intuitively as well.

****
Insert Table 3 about here.
****

This structured description of the doctor's task, and differentiated assignment of cognitive mode to the subtasks, gives Dreyfus and Dreyfus a complicated framework from which to advise medical students about their modes of cognition:

1. Realize that expertise is acquired step by step. One must learn the components explicitly and learn to act with them analytically. Experience will allow thinking about patients to become intuitive.
2. Avoid trying to think like an expert (intuitively). Without experience based on an analytic foundation, intuitive performance will be poor. Not using rules is a privilege of the expert, not a route to becoming expert more quickly.
3. Instead, practice intensively using the rules and logic that are available, whether these be the rules for performing a skill or the rules for judging what is important and deciding what to do.

In addition, the field as a whole should not rely too heavily on aids that take the rule-like decisions out of peoples hands, e.g., rule-based expert systems (or to use the Dreyfuses' term, "competent systems"), for this may deny students the opportunity to develop their expertise.

How valid is the Dreyfuses' theory? The authors support it by demonstrating its logic, citing evidence from the literature, and giving examples that connect with the readers' own experience. For example, a study of the acquisition of nursing expertise describes beginning nurses as rule-bound and lacking intuition about what is important (Benner, 1984). On the whole, the description of the move from analysis to intuition with the development of expertise seems correct, although the stage structure of their theory may invite them to make more distinctions than are necessary. Because the authors' disciplines, philosophy and operations research, do not demand that their theory be supported by a program of empirical research, the theory has not been subjected to the kind of test that would build one's confidence in all its details.

6 Comparison with Cognitive Continuum Theory.

The clinician interested in improving his or her reasoning about patients may ask whether it is necessary to understand both theories, since each uses the concepts of intuition and analysis. We now compare the two theories, highlighting especially the important differences that have practical applications. Medical practitioners should be cautious in applying the controversial aspects of either theory until the issues are resolved through research.

Cognitive Continuum Theory emphasizes that the task features determine the doctor's mode of cognition and indirectly his or her accuracy. Such factors, and particularly the effects of social and institutional setting on a doctor's cognition, are largely ignored by the Dreyfuses.

The Dreyfuses, for their part, emphasize the relation of the doctor's thinking to his or her experience. For Hammond, experience figures indirectly in determining a doctor's mode of cognition in a particular case, through factors such as whether an organizing principle is known. But it is not assumed to play the paramount role, as it does in the Dreyfuses' theory.

In contrast with the untested theory of the stages of expertise, Cognitive Continuum theory, conceived in the the field of psychology, was designed to be put to the test. Studies by Goldsberry (1983), Hammond, Hamm, Grassia, and Pearson (1984), Hamm (1985), and Howell (1984) have explored major tenets of the theory, and found support for it, including verification of some nonobvious predictions.

6.1 Similarities between the Theories.

The most important agreement is the assumption that people have the option of using analytical and intuitive modes of thinking. Though the theories' definitions of intuition (and analysis) are not identical, it is clear that they intend the same basic concepts.

Neither theory views intuition as a mere "automatization" of the processes involved in analysis. Intuition is not just a faster, unconscious performance of the analytic thinking processes, according to Cognitive Continuum Theory. It specifies a number of features on which the results of a doctor's intuitive thinking are different from the results of analytical thinking (e.g., in the pattern of errors, the consistency, and the rule relating the answer to the input information). Dreyfus and Dreyfus argue that intuition is different in kind from analysis, because analysis involves symbolic thinking while intuition does not (see Section 6.4 below).

Both theories say that in order to predict the accuracy of a doctor's performance, we must know something about both cognition and its context. For Hammond, the key context is task: performance is relatively most efficacious when the mode of cognition corresponds to the task features, and also when the problem is approached with the appropriate level of cognition and task features. For the Dreyfuses, the relevant context is the doctor's level of expertise -- performance is most accurate when the doctor's cognitive mode is appropriate to his or her experience, for each level of the task.

6.2 Similar Predictions for Different Reasons.

There are several issues on which the two theories predict the same kind of phenemonon, but for different reasons. For example, both theories value intuition and say it can be better than analysis on the same task, i.e., produce more accurate answers. For the Dreyfuses, this occurs because only intuition can bring into play the doctor's deep understanding of the situation. It is the expert doctor's intuition that enables him or her to deal with unexpected situations, where the usual rules don't apply.

Cognitive Continuum theory similarly predicts that intuition will be better than analysis in situations that are somewhat novel, but this prediction derives from an understanding of the organizing principles typical of analysis and intuition. Analytic organizing principles use only a few cues, in a precise manner, while intuitive organizing principles use many cues imprecisely, as by giving them approximately equal attention. If the doctor's situation is somehow different from the situation for which the analytic rule was produced, then the doctor may do better using intuitive cognition than by using the precise, but wrong, rule (see Einhorn and Hogarth, 1981). Thus, a particular test may define exactly whether a person has this year's variety of the flu; but at the beginning of next year's flu season the doctor will be better off looking intuitively at a patient seeking a flu-like pattern, than relying on the test, because next year's flu may be a variety to which the test is not sensitive.

Both theories expect the predominant mode of cognition to change from analysis to intuition in the course of the medical education. Hammond and Hamm (1983) attribute this to the change in the medical students' task characteristics, which shift from the analysis-inducing environment of the lecture hall and lab to the intuition-inducing clinic. Dreyfus and Dreyfus would attribute the same change from analysis to intuition to the students' increasing expertise rather than to the task environment.

6.3 Contradictions between the Theories.

Issues on which the theories disagree about the causes or advantages of the use of particular modes of cognition are the most important aspects of a comparison, for practical and theoretical reasons. Practically, until an issue is resolved, doctors will reasonably hesitate to use the conflicting advice. In the realm of theory, future progress in explaining expert cognition depends on the correctness as well as the richness of a theory's description.

What are the possible forms of quasirational cognition? While Hammond considers analysis and intuition the end points of the Cognitive Continuum, Dreyfus and Dreyfus speak only of the two pure types of cognition. They claim these are very different in principle, carried out by different processes (symbolic versus nonsymbolic). Therefore they would not endorse Hammond's notion of quasirational cognition as the middle range on a continuum, the type of cognition whose intermediate features reflect an intermediate cognitive process. However, the other two forms of quasirationality -- mixtures of analysis and intuition, and alternation between analysis and intuition -- would be consistent with their theory. Research strategies hinge on this issue (Hammond, 1981).

Are doctors more likely to use analysis or intuition when they are unfamiliar with a task? In Cognitive Continuum Theory, unfamiliarity of task content is a feature that induces intuition because, not having been trained to use any particular analytic principle for organizing their thinking about the situation, doctors will rely on the intuitive method for integrating information -- averaging. For the Dreyfuses, the novice is by definition unfamiliar with the task, and can only do it by taking an analytic, step by step approach. This contradiction may be explained, within a Cognitive Continuum theory framework, by a key difference in the task features -- novices in the teaching contexts the Dreyfuses discuss have these step by step analytical rules available in the minds of their teachers or in their texts -- in fact the educational environment is designed to provide them with these analytical organizing principles. However, there are no such aids in the general case Hammond speaks of, and so the clinician with an unfamiliar problem will use the default organizing principle, the averaging characteristic of intuitive cognition.

Does the quality of a doctor's reasoning depend on whether it is done analytically or intuitively? Both theories argue that it does, in particular contexts; but the particulars are quite different. For the Dreyfuses, better thinking is done intuitively, because experts, who think better, think intuitively. A major theme of their book is the fallibility of analysis. In Cognitive Continuum Theory, the relation of a doctor's performance to his or her use of intuition is an empirical issue, likely to depend on the task characteristics. Even if experts <u>prefer</u> to use intuitive cognition because it takes less time and effort, this does not mean it will be more accurate than analysis. Evidence that experts' intuition can be inaccurate (see Adelson, 1984) includes the discovery of widely divergent intuitive judgment policies used by expert medical specialists (Kirwan et al, 1983) and the finding that clinical psychologists' diagnostic judgments are not as accurate as mathematical models (see Dawes, 1979; Goldberg, 1970).

Should experts' instructions to novices be viewed as repetitions of the lessons that the experts originally heard when then were learning, rather than as indications of how they think? Perhaps this makes sense when one considers the game of chess, one of the Dreyfuses' examples, which has changed little in decades. But for a rapidly changing field such as medicine, teachers' lessons represent their best <u>current</u> understanding of good practice. Further, in their practice, the experts use the rules they tell the student. Much of medicine is carried out with a quasirational mode of cognition, say Mode 5 or Mode 4, as when the doctor plays a leadership or coordinating role in a group. The explicit expression of reasoning plays an indispensible role in such a group's decision making, and is not merely a remnant from the doctor's student days that has no function in his or her current thinking.

Do experts usually perform with fully intuitive cognition? The Dreyfuses think so, and judge it good that they do. For Hammond, experts perform at a variety of cognitive modes, depending on task, and this variation is good because research has shown that experts' intuition can be quite inconsistent and inaccurate.

6.4 Complementary Aspects of the Theories.

The Dreyfuses' theory of the different psychological processes that underly analysis and intuition complements the methods Hammond recommends for studying the two modes of cognition. The Dreyfuses believe that the processes involved in analytic cognition are quite distinct from those of intuition, whether these be embodied in human brains or computers. Analytic thinking involves the manipulation of symbolic propositions, the kind postulated to underly <u>all</u> problem solving by Newell and Simon (1972). But the processes underlying intuitive thinking are not symbolic, and are currently best modeled by a very different class of computer techniques, parallel distributed systems (e.g., Rumelhart et al, 1986; Smolensky, 1986).

Cognitive Continuum Theory does not describe the kind of information processing that underlies analysis and intuition. But it recommends that different techniques be used for describing the cognitive modes, based on the features of analytical and intuitive cognition (Hammond, 1981; 1983; Hammond, Hamm, Grassia, and Pearson, 1984). It would be appropriate to describe analytical cognition by analyzing verbal protocols and producing computer programs to simulate the cognition discovered there (Ericsson and Simon, 1984), because analysis has rule-like organizing principles and people are capable of reporting these rules. Hammond recommends describing intuitive cognition with statistical models (e.g., Brunswik's Lens Model) that express the answer as a weighted average of the available information, both because such models work well with intuitive cognition (see Hoffman, 1960; Einhorn, Kleinmuntz, and Kleinmuntz, 1979) and because people are not able to report any rules of intuition (see Rouse and Morris, 1986).

These approaches are complementary because Hammond's methods map onto the Dreyfuses' processes. The same protocol analysis methods Hammond recommends for describing people's analytic cognition have proven useful for studying the cognition-by-symbol-manipulation process that the Dreyfuses say underlies analysis. The methods Hammond uses for describing people's intuitive cognition (statistical modeling of the relation between the answer and the given information) are based on assumptions (Brunswik, 1956) very similar to the assumptions of the nonsymbolic paradigm of cognition (Smolensky, 1986).

7 Conclusion.

The medical student or clinician wishing to reason well about patients will gain from recognizing that there are different modes of cognition, analysis and intuition; that each is likely to occur in some contexts but not in others; and that in some situations each is the best thinking the doctor can do for the patient. The two theories reviewed in this paper have different frameworks for explaining the occurrence of the different modes of thinking and recommending their use. Hammond's Cognitive Continuum theory calls our attention to the task conditions in which the clinician must think. Dreyfus and Dreyfus's theory focusses on the changes in the doctor's own level of expertise.

Together, the two theories provide an explanation for variations in cognition on different tasks and at different stages of a doctor's career. They make suggestions for how to change cognitive mode, task characteristics, or (most difficult) one's own level of expertise, in order to improve accuracy. They also provide a framework for selecting techniques that help one reason normatively under different task conditions.

The theories can not provide step by step instructions on how to discover the appropriate reasoning strategy and use it. Clinicians will need to develop their own abilities to judge task situations and select appropriate modes of cognition.

The existence of important contradictions between the theories will make the clinicians' task all the more difficult. Should they base their actions on the Dreyfuses' assertions that experts are necessarily intuitive, and that intuition is the preferable mode for an expert doctor to use? Or should they follow Cognitive Continuum Theory in assuming that the cognitive mode used by the expert will depend on characteristics of the task, as will the accuracy of intuition? No matter which theory seems more true, one will need to keep a critical eye on the theories, both watching one's own practice for evidence supporting or refuting the theories, and monitoring the research literature for relevant results.

The reader of the research literature should pay attention to the quality of the research. Good research will specify the mode of cognition being investigated, select research methods appropriate to that mode of cognition, and restrict generalizations to the mode of cognition studied. Even better research will look at several modes of cognition, using several methods (cf Hammond, Hamm, and Grassia, 1986).

The resolution of the issues concerning the definitions of analysis and intuition, the processes underlying them, and the conditions in which each produces accurate reasoning will be one of the interesting challenges facing psychologists and cognitive scientists in the coming years. The medical community will have an important role in demanding, supporting, and carrying out the research that will resolve these questions, and in using its results wisely.

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9 Table Captions

Table 1. Features characteristic of causal reasoning at each mode on the cognitive continuum.

Table 2. Features characteristic of decision making at each mode on the cognitive continuum.

Table 3. Cognitive mode used at each level of the task, at each stage of the development of expertise, in the theory of Dreyfus and Dreyfus (1986).

Table 2.

Features characteristic of decision making at each mode on the cognitive continuum

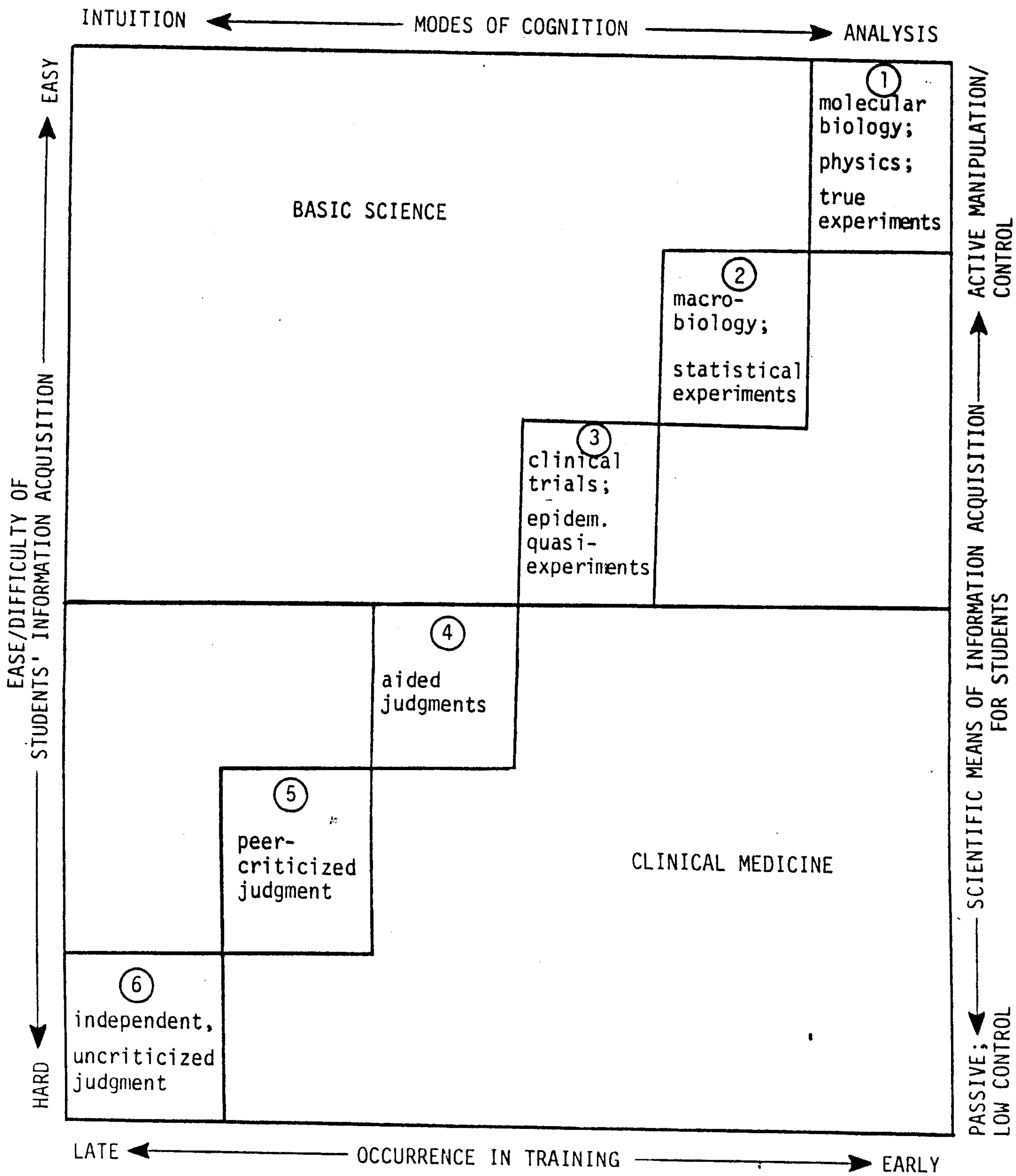
	Mode					
	Analytical				Intuitive	
Feature:	1 Formal Deduc-tion.	2 Clin. Trial per-spec-tive.	3 Epidem-iology per-spec-tive.	4 SEU with MD's assess-ments.	5 Group Dis-cuss-ion.	6 Uncrit-icized Decis-ion.
Decision structure, probabilities of events, and evaluation of outcomes are based on accepted, a priori models.	Yes	No	No	No	No	No
Probabilities and evaluations are based on controlled measurement of events and outcomes, at least.	Yes	Yes	No	No	No	No
Measurements of event probabilities and outcomes are based on statistical summaries of large amounts of data, at least.	Yes	Yes	Yes	No	No	No
Decision model is generated and probabilities and evaluations of outcomes are measured subjectively, at least.	Yes	Yes	Yes	Yes	No	No
Actions are justified with reference to reasons, rules, and principles, at least.	Yes	Yes	Yes	Yes	Yes	No

Table 3.

Cognitive mode used at each level of the task, at each stage of the development of expertise, in the theory of Dreyfus and Dreyfus (1986).

Level of Organization	LOWER		HIGHER	
Subprocess / Stage	PERCEPTION Perceives the elements of the situation.	ACTION Acts on those elements.	ORIENTATION Recognizes whole situations.	DECISION Makes decisions and plans how to attain goals in the situation.
1 Novice	Analytical	Analytical	Rely on others	Rely on others
2 Advanced beginner	Intuitive	Analytical	Rely on others	Rely on others
3 Competent	Intuitive	Intuitive	Analytical	Analytical
4 Proficient	Intuitive	Intuitive	Intuitive	Analytical
5 Expert	Intuitive	Intuitive	Intuitive	Intuitive

Figure 1


INTUITION
MODES OF COGNITION
ANALYSIS
EASY
EASE/DIFFICULTY OF STUDENTS' INFORMATION ACQUISITION
HARD
ACTIVE MANIPULATION/ CONTROL
SCIENTIFIC MEANS OF INFORMATION ACQUISITION FOR STUDENTS
PASSIVE; LOW CONTROL
BASIC SCIENCE
1 molecular biology; physics; true experiments
2 macro-biology; statistical experiments
3 clinical trials; epidem. quasi-experiments
4 aided judgments
5 peer-criticized judgment
6 independent, uncriticized judgment
CLINICAL MEDICINE
LATE
OCCURRENCE IN TRAINING
EARLY