Research to Understand and Improve the Exercise of Diagnostic Reasoning.

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Abstract.

In many fields professional decision makers must "diagnose" -- assess the present, uncertain situation and categorize it -- with different actions depending on those categories. Errors of diagnosis are common, and consequential. Research can identify both the relevant information for the categorization, and the optimal rules or concepts for combining that information, but frequently the information is not used in the recommended way. There is need for research on how people comprehend relevant information, the effective ways of using diagnostic information, and how their operational setting can be designed to offer the best support (information, and task design) for their diagnostic reasoning. Research progress on diagnosis would be applicable to medical, economic, industrial, military, intelligence, and other domains in which assessments of the situation must be made using incomplete and imperfect information.

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Society depends on individuals to accurately perceive particular situations, as a basis for acting according to their specialized roles (e.g., managers, physicians, teachers, police). In security, that means to recognize a threat; in medicine, to diagnose the identity of a patient's disease. In other fields the vocabulary, the particular content, and some of the basic characteristics are different, but the essential problems are the same.

How to improve practitioners' ability to accurately comprehend or categorize the situation is an essential question in any field. In medicine, for example, much is known about how to use uncertain information to diagnose patients, but the continuing prevalence of diagnostic errors attributable to human cognition indicates that this knowledge is not consistently applied by all practicing physicians. Similar observations could be made in clinical psychology, social work, or police work. The analogous problem is even more complicated in other domains: in security because individual acts by thieves, spies, or terrorists are so rare; in economics or politics because the status of a particular entity depends not only on its features but on the states of other entities.

The grand challenge here may be stated as, how may we get practitioners to use the optimal reasoning, and the system they practice in to provide the appropriate coordination, so that full advantage is taken of all the available information in an optimal manner and without avoidable errors? Further development is needed of the scientific basis for understanding the psychology of diagnostic reasoning in the contexts where it is practiced.

Let us consider the problem as it is manifest in medical diagnosis. The scientific basis for effective diagnosis by physicians includes the psychological sciences, with their descriptions of how physicians do diagnostic reasoning; the information sciences which study ways of providing doctors access to knowledge (about diagnosis, and about the patient in particular) in the clinic; and the system sciences which have ways of describing how all the parts of the clinic work together. Jointly these source disciplines provide a description of how diagnosis is actually done, in clinical settings. This description also provides the basis for analysis of what sorts of accuracy are possible with such a system, and identification of targets for improvement, whether they be ways of thinking, ways of providing or manipulating information, or ways of reorganizing the system and redefining the diagnostic task.

Current state of research.

Need for the research: Diagnosis is not accurate enough in practice. In each application area, there is much to gain from a better understanding of the determinants of accurate diagnosis. In medicine, diagnostic error is common, and major proportions of the errors identified by physician self report, patient report, and medical record review are due to physician cognition (diagnostic competence and performance); similar proportions are due to system factors. Despite advances in medical science and in the availability of information, the prevalence of diagnostic error is not rapidly decreasing. Many reasons for this have been identified: The organization of work keeps changing, with less time per patient, coupled with more demand to focus on distracting technical details (forms for documentation for billing, medical records of great complexity). Similarly the complexity of what medical education must cover is increasing. Further, diagnostic procedures contribute to the increase of medical costs beyond society's or individuals' ability to sustain, which means there is a need for physicians to identify and use more cost effective diagnostic strategies.

Previous research: Laboratory and analytic bases for accurate diagnoses. Diagnostic practice rests on an extensive foundation of research. There have been great advances in pathophysiological understanding; the development of chemical assays, imaging technologies and other diagnostic procedures, as well as studies identifying the clinical information that is most useful for diagnosis. The optimal diagnostic strategies have been articulated in an increasing number of clinical domains using special statistical techniques, including Receiver Operating Curve (ROC) analyses, multivariate combinations of clinical data, assessments of the value of information, and many others.

Previous research: Psychological science about diagnostic processes. There has been extensive research on how physicians think when making diagnoses. Based on general theories (such as those reviewed by Elwyn, Stiel, Durand, & Boivin, 2010), psychologists have investigated clinicians' representations of knowledge (memory, categories prototypical and fuzzy, gist) and their reasoning processes (explicit rules and strategies, and intuitive leaps based on instinct or long experience). Generic strategies for utilizing information in diagnosis have been extensively explored, showing that the general population uses a variety of heuristic strategies. For example, non-physicians, when asked the likelihood of the disease given a symptom, would attend to the commonness of the symptom in patients with a disease; this can lead to neglect of the disease prevalence or base rate. Physicians may employ the same strategies, when asked to estimate a patient's disease probability. However, they don’t commonly rely

on the explicit estimation of probabilities when diagnosing patients. Instead they typically follow a habitual routine or script for arriving at a diagnosis, involving recognition of one or two possible causes for the patient's complaint, and recall of what to do given each possibility. Though physicians may not be vulnerable to the pitfalls of particular heuristics for interpreting probabilities, this also implies that they are not benefitting from the useful tool of probability. Thus, we know something about why physicians have trouble with diagnostic reasoning. We don't know how to compensate for these flaws.

Previous research: The system in which the physician is embedded. There has also been research relevant to the way diagnosis is accomplished within the health care system. Psychologists studying decision making in its operational context have recognized that settings are often dynamic, that diagnosis of the state of the situation is embedded in a complex web of actions and information, and that successful experts recognize aspects of situations as familiar and recall what works in such situations. Medical diagnosis takes place in this sort of complex system, where the information depends on many people (patient, family, laboratory technicians, consulted specialists, nurses and clerks entering information, geeks maintaining the information technology), and can change over time. When the essential information may have been recorded incorrectly, delayed or lost in transmission, or superseded, there is opportunity for diagnostic error over and above any shortcomings in the physician's cognition. And the system introduces additional opportunity for the clinician to err, due to requiring additional cognitive tasks: as when the diagnostic task is put on hold awaiting more information, and then its pending status is forgotten.

Research needing support.

To promote better use of information in applied contexts, research is needed in multiple disciplines that have bearing on the design of work tasks, the design of work systems in which people do those tasks, the provision of information relevant to diagnosis, and the manner in which diagnosers interpret and use such information. Again, medical examples illustrate general needs.

Research in diagnostic disciplines. There is need to continue developing 1) data and procedures for probability revision that address the interdependencies of information, beyond the "naïve Bayes" which assumes findings have independent impacts; 2) data and ways of expressing imprecision, such as belief functions; 3) data and ways of expressing the usefulness of yet unknown information, such as its potential to reduce entropy or uncertainty; 4) data and ways of expressing diagnostic implications that can be interpreted by all physicians, in particular by those without training or interest in reading and

applying statistics; 5) non numerical rules or strategies that preserve most of the accuracy of numerical rules.

Research on diagnostic reasoning in the domain of application. There is need for research on how people think about assessing the situation in each particular domain, e.g., for medical diagnosis, on the psychology of physicians' diagnostic reasoning, on the way diagnosis is situated in the complex social and informational system of the clinic or hospital, and on ways to improve how information technology supports accurate diagnosis.

Psychology. How can the optimal diagnostic analyses' insights be made more accessible for physicians? Few medical students retain the formulas of Bayes' theorem or information theory and apply them in their clinical years. Should efforts to improve the individual's cognition focus on pattern recognition and categorization, or on probabilistic reasoning? Physicians' routine perception starts with category recognition, while the optimal utilization of information refers to probabilities, or probability-weighted utilities. Would there be larger increases in diagnostic accuracy if medical school emphasized training to better recognize patterns, or to better judge likelihood? How could pattern recognition skill or probability judgment skill be best trained during medical education? Is it better to address physicians' pathophysiological understanding so they can reason with reference to the causes of symptoms, or their grasp of the probabilistic relations so they can reason with respect to the likely associations between diseases and symptoms?

Assuming comprehension of likelihood is essential, which alternative forms of communicating it work better, are easier to teach people to interpret, produce more accurate results when manipulated by practitioners in real contexts, are robust to varying contexts, and are more easily made available when needed? Should physicians be expected to perform the calculations required by Bayes' theorem, or are the heuristic strategies that usually produce approximately correct answers adequate? How should disease likelihood be expressed? Thinking in probabilities (pre test probability, sensitivity, specificity, posttest probability) is awkward (requiring multiplication, addition, and division); thinking in odds (pre test odds, likelihood ratios, post test odds) may be easier (multiplication); thinking in log odds (log pre test odds, log LR, log post test odds) may be easier still (requiring addition). Though these alternative methods have been developed, their relative ease and relative accuracy given adequate training have seldom been compared in educational or operational settings.

Perhaps the everyday language of practitioners needs to have added to its vocabulary new concepts, to convey key insights about diagnosis. There has been little exploration of the use of

information about the uncertainty reduction that available information (potential questions, physical exam foci, tests) might provide in clinical diagnosis. How useful would physicians find this meta information? How should it be best expressed: informativeness (potential uncertainty reduction), or cost-informativeness (cost per unit of informativeness)? What burden should be placed on education, and what on the support provided by information technology, for assuring that physicians comprehend diagnosis-related information?

Systems. The focus on the individual clinician misses that the clinician is integrated in social (patient and family; staff and colleagues), organizational (clinic procedures) and information (computers, medical records, electronic orders and lab reports) systems, which have their own errors as well as introducing errors at the human-system interface. Information technology has benefits of providing more information and analytic interpretations, but also has effects which may reduce the quality of diagnosis. When a computer program interprets information, the physician potentially becomes dependent, loses the skill of doing the interpretation him- or herself, and comes to accept the computer interpretation uncritically. The physician's diagnostic skill may become less robust to disruption (computer breakdown or power outage), and less transferable to other practice settings. Further, when enfolded into an information system's total environment, the physician absorbs the values that were central to the system's design, such as recording billing-related information rather than diagnosis-relevant information, or maximizing the ease with which patients are referred to diagnostic technology profit centers without consideration of inconvenience to patient or cost to patient and society.

Interface of psychology, information technology, and systems research. Given an understanding of the way the physician's cognitive processes work when making a diagnosis, whether consciously "reasoning" about the diagnosis or not, is there a way that the "cognitive architecture" of the tasks in the physician's information environment might be designed to promote more accurate reasoning? For example, the medical record might selectively offer the opportunity to record the most useful information, contingent on the patient's presenting complaint, rather than having the physician seek out all the categories on multiple screens. Diagnoses might be more accurate if the physician registers symptoms (thus stimulating the recognition and reflection processes necessary for diagnosis), and the medical record software then suggests diagnoses to consider, than if the physician registers diagnoses (for billing purposes) and the medical record software then suggests symptoms (for documentation purposes to justify the bill in case of audit). While medical record systems that offer some such

intelligent functionality already exist, analysis of which findings to prompt has not been done, and effects of using such a system have not been scientifically evaluated.

Conclusion.

There is potential to improve our understanding of how people think when seeking and interpreting information, and how systems influence diagnosis and how diagnosers can better be integrated into and supported by the systems. Work here could have an impact on practice and education in multiple fields of application.

Many disciplines could potentially contribute to this work. For diagnosis or categorization in any applied field, research involving psychology, human factors, operations research and optimization, decision sciences, systems science, behavioral economics, information sciences and computer system design, technology assessment, and sociology may be appropriate. For each particular field of application the involvement of subject matter experts and expert practitioners is of course essential, whether it be medicine, other clinical fields, law, the military, security, intelligence, business, finance, management, or auditing.

Elwyn, G., Stiel, M., Durand, M. A., & Boivin, J. (2010). The design of patient decision support interventions: addressing the theory-practice gap. *J Eval Clin Pract*.