How Neurologists Think
A Cognitive Psychology Perspective on Missed Diagnoses

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Physicians use heuristics or shortcuts in their decision making to help them sort through complex clinical information and formulate diagnoses efficiently. Practice would come to a halt without them. However, there are pitfalls to the use of certain heuristics, the same ones to which humans are prone in everyday life. It may be possible to improve clinical decision making through techniques that minimize biases inherent in heuristics. Five common clinical heuristics or other sources of cognitive error are illustrated through neurological cases with missed diagnoses, and literature from cognitive psychology and medicine are presented to support the occurrence of these errors in diagnostic reasoning as general phenomena. Articulation of the errors inherent in certain common heuristics alerts clinicians to their weaknesses as diagnosticians and should be beneficial to practice. Analysis of cases with missed diagnoses in teaching conferences might proceed along formal lines that identify the type of heuristic used and of inherent potential cognitive errors. Addressing these cognitive errors by becoming conscious of them is a useful tool in neurologic education and should facilitate a career-long process of continuous self-improvement.

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Case #1: Framed in Mexico

A visiting professor is presented with a case initially summarized as "a 49-year-old woman who developed rapidly progressive weakness while vacationing in Mexico." Shortly after traveling to Mexico for vacation, the woman developed mild muscle pain in her thighs. A week after onset, she noted leg weakness and tripped on a step going into a restaurant for dinner. During dinner, she became unable to stand, needing a wheelchair to return to her hotel. The next day, she awoke with upper extremity weakness that rapidly progressed to involve her trunk and neck. On admission to a hospital in Mexico, her respiratory status was stable, but she could not move her arms and legs.

Past medical history included thrombotic thrombocytopenic purpura (TTP) 8 years earlier treated with splenectomy. Review of systems showed long-standing facial paresthesias and dry mouth, but no fevers, night sweats, or recent upper respiratory or diarrheal illness.

Her vital signs were normal, and she had no respiratory distress. Her mental status was normal. There was mild weakness of the trapezii and sternocleidomastoids without facial weakness, ptosis, or ophthalmoparesis. Speech and swallowing were normal. She complained of facial paresthesias but had no objective sensory loss. There was bilateral severe proximal worse than distal muscle weakness in all 4 extremities. Limb tone was decreased, and there were no fasciculations. Sensory, coordination, and deep tendon reflex examinations were normal; there were no Babinski signs.

The visiting professor was asked to comment on diagnoses initially entertained by the house staff. He discounted Guillain-Barré syndrome because of the normal

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deep tendon reflexes and excluded myelopathy because of lack of sensory findings and absent Babinski signs. He confidently made the diagnosis of acute trichinosis acquired in Mexico, with muscle pain followed by severe weakness due to an inflammatory myopathy, with typical proximal worse than distal weakness, sparing of respiratory muscles and face, and preservation of muscle stretch reflexes. His rationale for trichinosis was that there must be a tie to onset of the illness in Mexico.

Subsequently, he was presented with laboratory findings including serum potassium = 1.6 meq/L (with a corresponding abnormal electrocardiogram), erythrocyte sedimentation rate = 68 mm/hr, antinuclear antibody > 1:640, rheumatoid factor = 134 Iu/mL, and presence of antibodies to Sjögren syndrome A and B. The diagnosis was in fact rapidly progressive weakness due to hypokalemia from a distal renal tubular acidosis caused by Sjögren syndrome, either primary or secondary to systemic lupus erythematosus.

Framing Effects

"A 49-year old woman developed rapidly progressive weakness while vacationing in Mexico." Like most of us, the visiting professor was undeniably swayed by the leading aspects of the initial information, influencing him to propose a diagnosis connected to an exposure in Mexico. In retrospect, other components of the history—particularly the history of TTP, suggesting an autoimmune syndrome, and the review of symptoms for dry mouth and facial paresthesias, suggesting Sjögren syndrome—were ignored.

Cognitive Psychology of Missed Diagnoses and the Use of Heuristics

A premise of cognitive psychology, "the science that examines how people reason, formulate judgments, and make decisions,"[1] is that errors in diagnostic reasoning are due to predictable categories of cognitive errors to which all clinicians—indeed, all people—are prone. The volume and complexity of information amassed while formulating a clinical diagnosis in neurology may be enormous. Without explicitly realizing they are doing so, clinicians use heuristics in their diagnostic reasoning. In a medical context, heuristics are shortcuts or experience-based techniques that help physicians in rapidly synthesizing clinical information to come to a diagnosis or a ranked set of potential diagnoses. Such shortcuts are not only common but are necessary, because they lead to correct diagnoses in an efficient time frame. Thus, the ultimate goal of correcting errors in neurological diagnosis is not to eliminate the use of heuristics, but to become aware of ones having inherent pitfalls and to have access to a menu of corrective strategies.

Revisiting Case #1: Framing Effects

Framing refers to the error of initiating diagnostic reasoning by overvaluing an item of clinical information that is presented early in the process. In the example, one can imagine that the case could have been presented to the visiting professor as "a woman with rapidly progressive weakness and a history of TTP." The professor might have focused on an alternative diagnosis if the case had been so framed. However, awareness of the phenomenon of framing effects could have led the professor to weigh the alternative pieces of clinical information as strongly as the information about geography.

What Is the Evidence for Framing Effects?

One model for predicting how humans make decisions states that how information is framed does not affect people's decision making. This principle of invariance underlies the rational or normative model of decision making. However, a body of scientific research refutes this principle.[2] In 1 example, obstetrical residents were presented with 3 clinical vignettes that included graphs of progression of labor as shown by a plot of dilatation of the cervix (y-axis) versus time (x-axis).[3] The study participants were asked to specify how they would manage each case, and management decisions were subsequently categorized as either active intervention, or continued observation and assessment. To test the principle of invariance, each participant was actually given each case twice, 2 months apart. The only difference in each pair of presentations of a given case was the ratio of the x- to y-axis, so that in 1 the graph of dilatation of the cervix over time appeared to be steeper, and in the other it appeared to be shallower. However, the actual rate of progression of labor was identical across each pair of versions of each case. The order in which the shallow versus steeper graph were given was randomized, and the study hypotheses were not revealed to the participating physicians.

The residents were significantly more likely to indicate that they would intervene in labor in response to the vignettes in which data were presented in the shallower format, compared with the vignettes in which the graphical data had a steeper appearance ($p < 0.05$; Fig 1). This study thus did not support the principle of invariance.

In another often-cited example of framing effects, McNeil and colleagues[4] studied veterans with various chronic diseases, radiologists, and graduate students at a business school. All subjects were asked for their preference for radiation therapy versus surgery as treatment for lung cancer. Radiation therapy was associated with worse 5-year outcomes than surgery, but surgery had worse short-term outcomes compared with radiation therapy, due to risk of surgical complications. Subjects in each

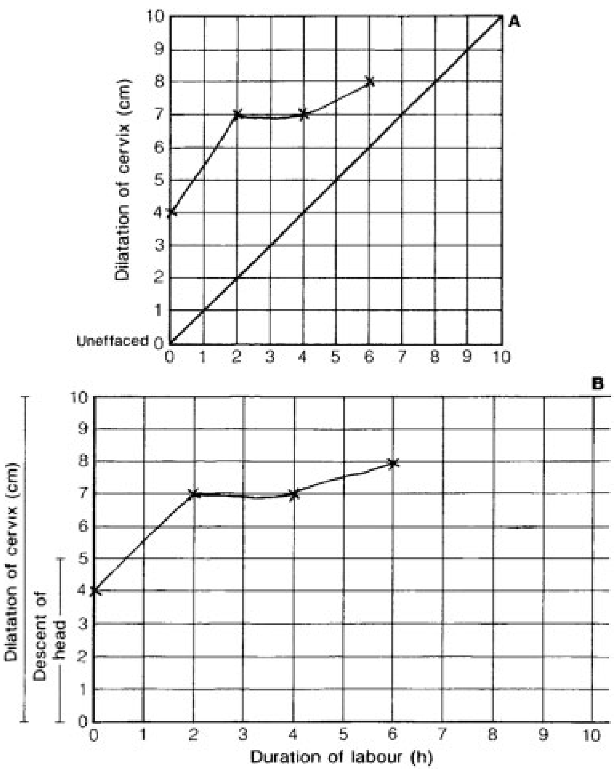

FIGURE 1: (A) Example case on steep (1/1) partogram; (B) same case on shallow (1.5/1) partogram. Sixteen obstetrical residents were asked whether they would intervene in labor for each of 3 cases (48 pairs of responses), based on the appearance of a partogram or graph of dilation of the cervix over time. The residents were given 1 of 2 different formats for each case, at 2 points in time separated by 2 months. Data for each case within a pair were the same, but the width of the x-axis differed so that the partogram appeared more steep in 1 case of the pair and more shallow in the other presentation of the pair. The order that each case within a pair was presented was randomized, and study hypotheses were not revealed to participants. Results were that in 18 of the 48 pairs, the management decision was the same across the pair of partograms, but in 21 of the remaining 30 pairs, the management recommendation was to intervene when the data were presented in the steeper format and not to intervene when the data were presented in the shallower format ($p < 0.05$). Reprinted from Cartmill RS, Thornton JG. Effect of presentation of partogram information on obstetric decision-making. Lancet 1992;339:1520–1522, with permission from Elsevier.

sample were randomized to receive information about short- and long-term outcomes of radiation therapy and surgery in alternative frameworks. In the "survival" framing, outcome data were framed in terms of how many people out of 100 *survived* (early and 5-year), and in the "mortality" framing, outcome data were framed in terms of how many people out of 100 *died* (early and 5-year; Table 1). The findings were that within each of 3 different samples of subjects (veterans with chronic diseases, radiologists, and business school graduate students), a significantly higher proportion of that sample of subjects who were given the outcomes in a survival framework indicated a preference for surgery compared with the proportion of subjects in that sample who were given the alternative framing of the outcomes in terms of mortality.

In summary, framing effects—although a useful heuristic with the strength of providing efficiency in thinking—can result in incorrect initiation of the process by focusing on certain aspects of a case in preference to others. A recommended debiasing or corrective strategy is to purposefully examine the case from alternative perspectives, re-evaluating different pieces of clinical information (ie, Descartes' "devil's advocate".)

Case #2: Anchored in an Initial Probability

A 75-year-old, active and healthy man ran a ranch for children with disabilities. Over 9 months he developed a "brain fog," with loss of energy and drive, and an inability to "get started" in the morning. He presented to a neurologist with a self-acknowledged depression, which he described as "fierce," "a black cloud hanging over my head," and "I don't take enjoyment in anything." Notably, there was no family history of dementia, suicide, or depression, and there were no recent life events that might trigger depression. General and neurologic examinations were normal. The neurologist diagnosed late-life depression, but an antidepressant trial resulted in no improvement. Six months later, the patient was referred to a psychiatrist. The psychiatrist judged that it was atypical for this degree of late-life depression to occur with no prior history of depression or recent major life stressors. The psychiatrist ordered labs including heavy metal screening, with findings of a markedly elevated serum mercury level (47 ug/dL; upper limit of normal = 9 ug/dL).

However, the neurologist did not believe that a depressive syndrome could occur with heavy metal toxicity. Despite several more antidepressant medication trials, the patient continued to become slower and more hypoactive. Finally, chelation therapy for mercury poisoning was begun, and the patient's symptoms resolved entirely over 6 weeks.

Anchoring

It is very common to formulate an initial probability of a diagnosis based on information at hand on the first assessment, with the understanding that the probability of this diagnosis will be adjusted as new clinical data—such as additional history, an opinion by a referring physician, or a test result—are obtained. Although this is a perfectly sensible approach, the potential pitfall of this heuristic is that it can yield biased estimates because clinicians (1) tend to place probability estimates at extremes near 0% or

TABLE 1: Examples of the Descriptions of the Consequences of Surgery and of Radiation Therapy for Lung Cancer Presented in a Survival Framing and in a Mortality Framing

Problem 1 (Survival Frame)
Surgery: Of 100 people having surgery, 90 live through the post-operative period, 68 are alive at the end of the first year, and 34 are alive at the end of 5 years.
Radiation therapy: Of 100 people having radiation therapy, all live through the treatment, 77 are alive at the end of 1 year, and 22 are alive at the end of 5 years.

Problem 1 (Mortality Frame)
Surgery: Of 100 people having surgery, 10 die during surgery or the post-operative period, 32 die by the end of the first year, and 66 die by the end of 5 years.
Radiation therapy: Of 100 people having radiation therapy, none die during treatment, 23 die by the end of 1 year, and 78 die by the end of 5 years.

A significantly lower proportion of veterans with chronic disease who were given the survival framing of outcomes indicated a preference for radiation therapy compared with the proportion of subjects who were given the mortality framing of outcomes (22% vs 40%; 119 veterans: 59 received survival framing and 60 received mortality framing); similar results were obtained when preferences were elicited from a sample of 167 radiologists (16% chose radiation therapy in response to the survival framing vs 50% in response to the mortality framing), and a sample of 297 graduate students at a business school (17% chose radiation therapy in response to the survival framing vs 43% in response to the mortality framing).
Data by subgroup are from Table 2 on page 1261 of McNeil BJ, Pauker SG, Sox HCJ, Tversky A. On the elicitation of preferences for alternative therapies. N Engl J Med 1982;306:1259-1262.

100%; and (2) fail to adjust probability estimates properly once new clinical information is obtained. In this example, the neurologist's estimate of the probability of late-life depression began at around 100% and a toxic cause at essentially 0%; further, these probability estimates were not adjusted until a number of months after new clinical data from the consulting psychiatrist were received. Biases against certain diagnoses such as encephalopathy occurring from heavy metal toxicity are a prime example.

Like other heuristics, anchoring is a much more general phenomenon. Tversky and Kahneman[5] illustrate the phenomenon of anchoring in this example. A group of subjects were asked to estimate the percentage of an item, for example, the percentage of countries in Africa that are members of the United Nations (UN). With the subjects present, a multiple of 5 (the anchor) between 0 and 100 was generated at random from spinning a wheel. Subjects were then asked to estimate the value of the item (ie, the percentage of UN member countries in Africa) by adjusting upward or downward from the number that the individual had observed to be obtained at random from spinning the wheel. The median of the final estimated percentage on the item was calculated for each subgroup of subjects that had received different values for the initial anchor, as spun on the wheel.

If there was no anchoring phenomenon, the median final estimated percentage of UN member countries in Africa should be the same, no matter what the initial anchor from which subjects were asked to adjust to generate their final estimate on that item. However, the scientists found that final estimates indeed did differ depending on the anchor value. For example, among the subgroup of subjects whose anchor in the example given was 10, the median final estimate of the percentage of countries in Africa that are members of the UN was 25%; however, among the subgroup of subjects whose anchor was 65, the median final estimate on that same item was 45%.

In summary, the pitfalls of the anchoring heuristic are the problem of placing the probability of particular diagnoses too far toward the extremes of 0% or 100%, and the tendency not to adjust diagnostic probabilities properly with additional clinical data. A corrective strategy is to formally estimate probabilities in light of the new data or the second opinion, or to look up selective probability data through searches of the medical literature. Clinicians could consider re-evaluating their patient as they would when they give a second opinion.

Case #3: A Readily Available Diagnosis

A neurologist was referred a 42-year-old teacher who had developed rapidly progressive dementia and an inability to walk over 2 months. She had a horizontal scar on her anterior neck. Neurological exam revealed severe abulia, spastic ataxia, preserved deep tendon reflexes, and bilateral Babinski signs. Cervical spine magnetic resonance imaging (MRI) showed a longitudinal white matter lesion in the region of the posterior and lateral columns. An electromyography/nerve conduction velocity study (EMG/NCVS)

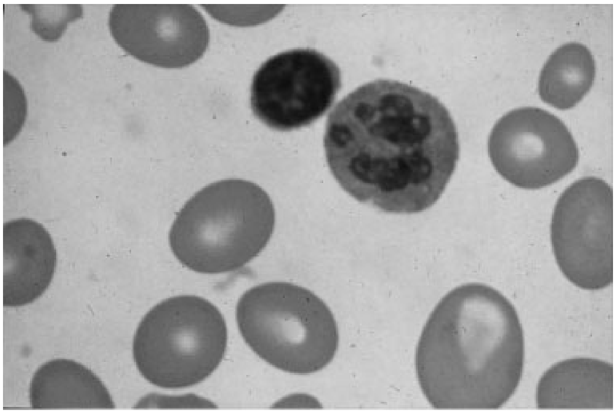

FIGURE 2: Peripheral blood smear from Case 3 of 74-year-old man having macrocytic, megaloblastic anemia.

showed no evidence of neuropathy. Hematocrit was 20%, mean corpuscular volume was 115 fL, and initial and repeat cobalamin levels were zero. She was diagnosed with pernicious anemia, treated with parenteral cobalamin, and back to work in 3 months feeling "better than ever."

A few weeks later, the same neurologist encountered a 74-year-old man with a 9-month history of gait disturbance characterized by incoordination, particularly when in the dark or the shower. He had no pain, but his legs felt numb. He had undergone a partial gastrectomy 20 years earlier for gastric bleeding and said that he subsequently took vitamin supplementation. Mental status and cranial nerve exams were normal. There was a profound loss of vibration sense from the waist down, and a floridly positive Romberg sign. Motor exam showed bilateral quadriceps atrophy with 4/5 symmetric proximal and distal lower extremity weakness. Deep tendon reflexes were normal in upper extremities with diminished patella reflexes and absent ankle jerks. There were bilateral Babinski signs. Gait was abnormal with evidence of spasticity. A cervical spine MRI showed a longitudinal white matter lesion in the region of the posterior and lateral columns, and a peripheral smear (Fig 2) revealed macrocytic, megaloblastic anemia.

The neurologist confidently made a diagnosis of cobalamin deficiency (in the setting of prior gastric surgery), the second case of cobalamin deficiency he had seen within a month. However, laboratory studies showed a normal cobalamin level (519 pg/mL). With this finding and on re-review of the neurological exam findings, an EMG/NCVS was ordered, revealing a generalized symmetric, length-dependent, axonal sensorimotor neuropathy. Additional workup yielded an abnormally low serum copper level and an elevated serum zinc level. On further questioning of the patient, he had revised his vitamin supplementation regimen in the prior year to include zinc. With repletion of copper and discontinuation of the zinc, the patient's syndrome remitted.

Availability Heuristic

The likelihood of a diagnosis is influenced by the ease of recall of similar examples. It is more efficient to draw on recollection and experience than to consider probabilities based on the features of every clinical case using population-based studies of prognosis. Indeed, needed probability data may be quite limited in many circumstances. However, there is the potential for bias due to ease of retrievability of prior experiences, either due to a prior case's proximity in time or its impact, as demonstrated in the following research studies.

To assess knowledge about transfusion risks, 122 surgeons and anesthesiologists were surveyed on whether they had ever had an adverse experience from withholding transfusion.[6] They were also asked their estimates of the risk of an adverse outcome from withholding transfusions in certain scenarios. The findings were that among physicians who had reported a prior experience of personally treating a patient who had suffered an adverse outcome that might have been avoided by a transfusion, the median risk estimates were twice as high as among those physicians without such a prior experience (10% vs 5%; $p = 0.03$). The mean actual risk, estimated by an expert panel, was 4% (range, 1%–5%), approximately the same as that of the physicians without a prior adverse experience.

In summary, the pitfall illustrated by the availability heuristic is the tendency to make a diagnosis based on the ease of recalling past cases, especially those that were recent or had a high impact. A corrective strategy is to verify with statistics based on the literature, and to question whether one is being unduly influenced by an experience with a memorable or recent case.

Case #4: Representative But No "Priors"

A 47-year-old state policeman presented to the neurologist with trouble with his vision at the shooting range. There had been a recent minor car accident. Aside from incomplete bitemporal visual field defects, the remainder of the neurological exam including visual acuity was normal. An MRI showed moderate hydrocephalus, and a lumbar puncture showed an opening pressure of 170mm H2O with no cells, normal protein and glucose, and a few bands. With a diagnosis of idiopathic hydrocephalus and chiasmatic compression, he had a shunt placed that was complicated by transsection of the internal capsule, resulting in a right hemiparesis. He recovered, but hemiparesis and visual trouble deteriorated again in 6 months, and he underwent several shunt revisions. Over 3 years, the patient had a slow and continuous mental decline to a demented state with confusion and hallucinations. He became blind, with normal optic nerve heads, visual evoked responses, and retinal examinations. White matter abnormalities that had been

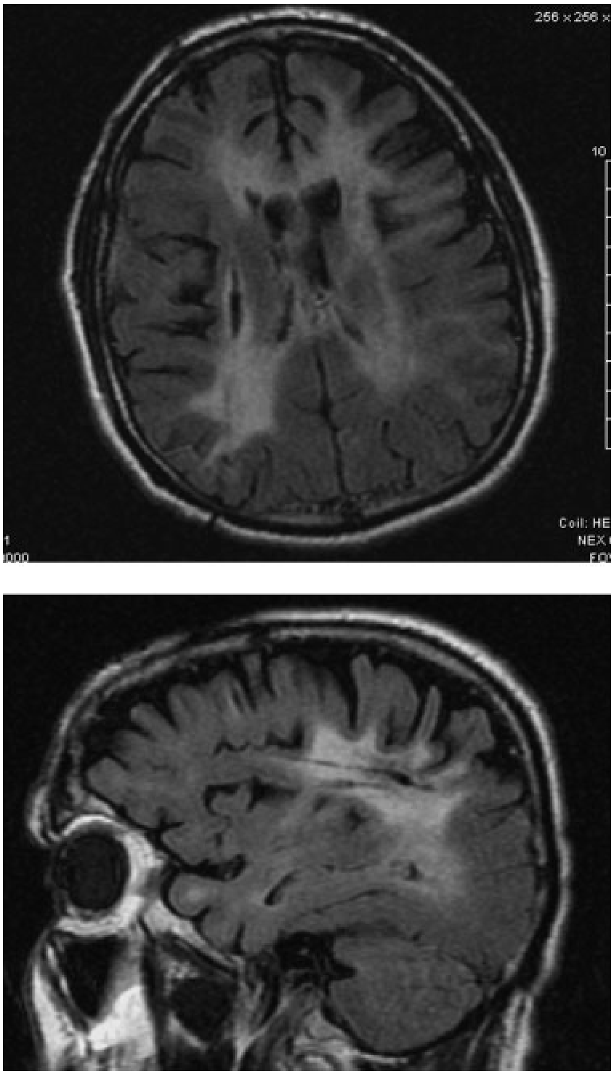

FIGURE 3: Brain MRI scans from Case 4, a 47-year-old with vision complaints.

present on the initial MRI did not change over time except for increasing gliosis along the shunt tracks (Fig 3).

Looking for a cerebrovisual degenerative process, the neurologist obtained a skin biopsy, which showed changes of neuronal ceroid deposition, but electron microscopy was more equivocal. The neurologist concluded that the diagnosis was Kufs disease. The patient continued to deteriorate and died blind, demented, and paraplegic. The autopsy showed mundane and widespread multiple sclerosis.

Representativeness Heuristic

Representativeness or pattern recognition is perhaps the most commonly employed and useful heuristic for clinicians. If a clinical presentation resembles other patients with a well-characterized disease, then the probability is high that the case is a presentation of that particular entity. However, a significant weakness of this heuristic, particularly in complex cases, is the tendency to ignore prior probabilities or base rates of the disease. In the preceding example, the prevalence of multiple sclerosis is 1 in 2,400. However, Kufs disease is much rarer, with only 50 verified cases in 1 comprehensive review.[7] Even dementia without visual failure is a priori more likely due to MS than to a storage disease.

There is strong evidence that the representativeness heuristic introduces errors in diagnostic reasoning because prior probabilities are ignored. Kahneman and Tversky[8] tested this general phenomenon by giving 2 experimental groups the same sets of 5 brief personality descriptions and asking them, following their reading of each of the 5 descriptions, to indicate whether the person described was an engineer or a lawyer. The factor that was randomized between the 2 groups was the prior probability of the person being an engineer or a lawyer. One group was told that the descriptions were sampled at random out of a group of 70 engineers and 30 lawyers, whereas the other group was told that the descriptions were sampled at random out of a group of 30 engineers and 70 lawyers. All subjects were given the exact same 5 personality descriptions (Fig 4), with the exception that they were reminded following that personality description of the prior probability for being an engineer or a lawyer.

Logically, the odds that any given description is of an engineer rather than a lawyer are higher for the group that was told that there are 70 engineers out of the 100 from which this description was sampled by random draw. If subjects took into account prior probabilities, a plot of the probability that the scenario was a description of an engineer in the group that was told there were 70 engineers out of 100 versus the group that was told there were only 30 engineers out of 100 should be curved (see Fig 4). However, the findings were that the relationship was instead linear; that is, subjects did not take into account the prior probabilities in making their estimates. For a given scenario, subjects in both groups generated the same estimate, indicating that they were basing their judgments entirely on stereotypes drawn from the personality descriptions. To explore whether this was because subjects did not understand how to use prior probability estimates, subjects correctly estimated probabilities when they were given a null description—that is, a description that contained no information about the individual chosen at random from the sample.

In summary, the pitfall of the representativeness heuristic is ignoring prior probabilities and base rate frequencies of different diagnoses that match a pattern of clinical presentation. The corrective strategy is to formally incorporate prior probabilities into diagnostic thinking and where necessary, consult the literature on prevalence and occurrence of different diseases. A traditional clinical maxim is to pay attention to base rate frequencies, that is, "if you hear hoof beats, think about horses, not zebras." Of course, base rate frequencies will be higher for rare diseases in tertiary referral centers than in general practice settings.

Case #5: Too Much Test Reliance

A 46-year-old man presented to his neurologist complaining of a gradually worsening generalized headache most distinctive because it was worse on standing and improved by lying down. Other than several injuries to the neck and head (without loss of consciousness) during past military service, past history was unremarkable, and his neurological examination was normal. A brain MRI including contrast was obtained (Fig 5A), showing pachymeningeal enhancement. The attending neurologist diagnosed spontaneous low pressure headache and advised the residents against lumbar puncture, due to risk of aggravating the headache.

However, the residents eventually obtained a diagnostic lumbar puncture, which showed an opening pressure of 160mm H_2O, white blood cell count = 37 mm^3 (15 neutrophils/mm^3, 15 lymphocytes/mm^3, 7 monocytes/mm^3, no atypicals), cerebrospinal fluid protein = 90 mg/dL, and a negative cytospin. A biopsy was interpreted as consistent with a granulomatous pachymeningitis (see Fig 5B). Syphilis serology was strongly positive in the blood and cerebrospinal fluid. In retrospect, the patient recalled having been

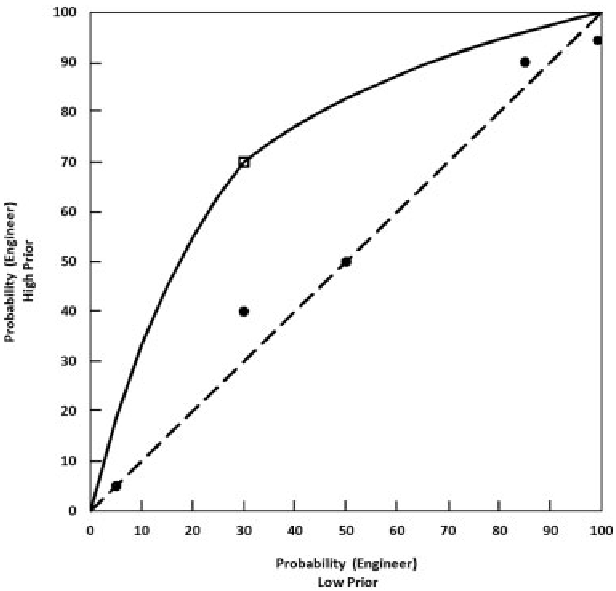

FIGURE 4: Example description for subjects who were told there were 30 engineers and 70 lawyers in the sample from which the description was drawn at random: "Jack is a 45-year-old man. He is married and has four children. He is generally conservative, careful, and ambitious. He shows no interest in political and social issues and spends most of his free time on his many hobbies which include home carpentry, sailing, and mathematical puzzles. The probability that Jack is one of the 30 engineers in the sample of 100 is ____%." The plot of the median probabilities for judging each of 5 descriptions (the 5 solid circles) represents an engineer, from subjects who were told that the descriptions were drawn at random from a set of 100 descriptions representing a sample of 70 engineers and 30 lawyers versus subjects who were told that the descriptions were drawn at random from a set of 100 descriptions representing a sample of 30 engineers and 70 lawyers. The curved line is the correct relationship based on Bayes' formula, which incorporates prior probabilities. The square represents the subjects' responses when given a null description and only the prior probability. Kahneman D, Tversky A. On the psychology of prediction. Psychol Rev 1973;80:237–251, with permission from the American Psychological Association.

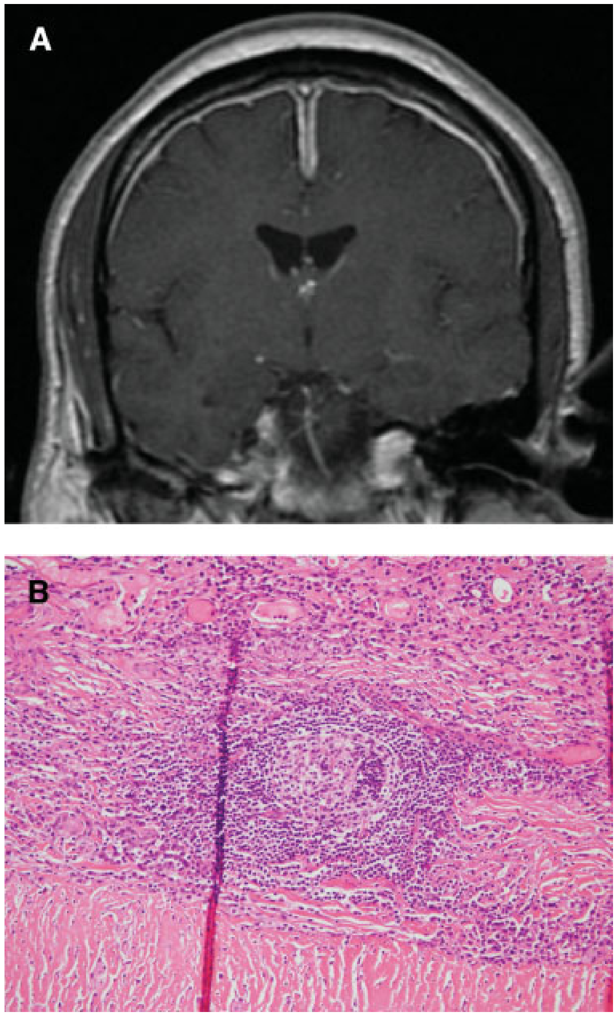

FIGURE 5: Case 5. (A) Brain magnetic resonance imaging with gadolinium of a 46-year-old man who presented with gradual worsening of a generalized headache, which was worse on standing and improved by lying down; he was initially diagnosed with low pressure headache. (B) Biopsy of same man; features are most consistent with a granulomatous pachymeningitis from syphilis.

TABLE 2: Selected Pitfalls Leading to Missed Diagnoses, and Corrective Strategies

Heuristic or Phenomenon	Pitfall	Corrective Strategies	Clinical Maxims	Illustrative Studies
Framing Effects:	Being swayed by subtle wording to focus on certain aspects of a case more than others	Examine case from alternative perspectives and re-evaluate different pieces of clinical information	Deliberately consider from another angle: *"Let's play devil's advocate" or "Let's re-review elements of the history"*	Cartmill, R.S.V. & Thornton, J.G; *Lancet*, 1992 McNeil et al; *NEJM*, 1982
Anchoring Heuristic:	Relying on initial impressions and not adjusting diagnostic probabilities properly with new data	Formally estimate probabilities in light of new data or second opinion; look up selected probability data on Pubmed; do this with *own* patient as you would when giving second opinion	*"If the patient is not responding to treatment or is worsening, is one possibility that this is the wrong diagnosis? Have I properly weighed key clinical data in making a diagnosis?"*	Tversky and Kahneman; *Science*, 1974
Availability Heuristic:	Judging by ease of recalling past cases based on recency or impact	Verify with legitimate statistics from the literature	*"Am I unduly influenced by my experience with one memorable or recent case?"*	Salem-Schatz et al; *JAMA*, 1990
Representative-ness Heuristic:	Ignoring prior probabilities and base rate frequencies of different diagnoses that seem to match the patient's pattern of presentation	Formally incorporate prior probability into considerations; look up literature on prevalence and occurrence of diseases	Pay attention to base rates: *"If you hear hoof beats, think about horses not zebras."*	Kahneman & Tversky; *Psychol Review*, 1973
Blind Obedience:	Showing undue deference to authority or technology	Look up diagnostic test performance characteristics in medical literature using Pubmed or other sources	*"Does a negative value on a test definitively rule out a disease? How common are false positives?"*	Woolf & Kamerow; *Arch Intern Med,* 1990

Adapted from Redelmeier DA. *Ann Int Med* 2005:142:119 (Table)

diagnosed with a venereal disease in the past during his military service.

Blind Obedience and Overreliance on Test Results

Diagnostic tests are never perfect in detecting or excluding disease.[9] If such information is not kept in mind, clinicians may hone in on a particular diagnosis based on a diagnostic test result without considering that test's sensitivity or specificity. The concept of blind obedience is more expansive than overreliance on technology, however, as it also encompasses the concept of undue deference to authority figures. In this case, both concepts are illustrated (although what is illustrated is the opposite of undue deference to authority). The brain MRI findings—although consistent with low pressure headache—were not at all specific for that diagnosis. Although the clinical characteristics of this case were also consistent with low pressure headache, other aspects of the history (as eventually obtained) and the additional testing pursued by the residents led to a substantially different diagnosis with a different treatment.

In summary, the potential pitfall of overreliance on test ordering (or blind obedience) is when undue deference to authority or technology leads clinicians in the wrong direction. Corrective strategies include consulting diagnostic test performance characteristics from the literature and applying maxims, such as "Does a negative value on a test definitively exclude a disease?" and "How common are false positives?"

Conclusion

In summary, physicians by necessity use heuristics to help them sort through complex clinical information and formulate diagnoses and treatment strategies.[10] There are, however, well-established pitfalls with the use of heuristics. Because these are general cognitive phenomena, it may be possible to improve decision making and reduce the occurrence of missed diagnoses by raising awareness and incorporating behavioral strategies to minimize bias (Table 2).[1,11] However, there is relatively little literature on designing and testing such debiasing protocols or algorithms in clinical work.[12] We have found that simply by incorporating the terminology of heuristics—specifically anchoring, framing, availability, representativeness, and blind obedience—into our teaching rounds, we have strengthened our and our residents' willingness to accept errors as part of clinical life and pause to consider their potential sources with each new case. With the introduction of increasing information technology capability in healthcare, there should be greater opportunities to access data to inform decision making in a timely fashion,[13] but it remains to be seen if these system support mechanisms can reduce the intrapsychic errors associated with clinical heuristics.

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Potential Conflicts of Interest

Martin Samuels was previously employed by M/C Communications and his wife, Susan Pioli is a senior member of the leadership group at the continuing education content company, Lighthouse Learning. Both Barbara Vickrey and Allan Ropper have spoken about this subject and paid for doing so.

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