Cognitive Processes in Anesthesiology Decision-making

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ABSTRACT

The quality and safety of health care are under increasing scrutiny. Recent studies suggest that medical errors, practice variability, and guideline noncompliance are common, and that cognitive error contributes significantly to delayed or incorrect diagnoses. These observations have increased interest in understanding decision-making psychology.

Many *nonrational* (*i.e.*, not purely based in statistics) cognitive factors influence medical decisions and may lead to error. The most well-studied include heuristics, preferences for certainty, overconfidence, affective (emotional) influences, memory distortions, bias, and social forces such as fairness or blame.

Although the extent to which such cognitive processes play a role in anesthesia practice is unknown, anesthesia care frequently requires rapid, complex decisions that are most susceptible to decision errors. This review will examine current theories of human decision behavior, identify effects of nonrational cognitive processes on decision-making, describe characteristic anesthesia decisions in this context, and suggest strategies to improve decision-making. **(ANESTHESIOLOGY 2014; 120:204-17)**

THE quality and safety of health care are under increasing scrutiny. Studies have suggested that health care is plagued with errors,[1] unexplained practice variability,[2–4] and guideline noncompliance.[5,6] These observations have led to increased interest in understanding decision-making cognitive processes and improving educational strategies for teaching decision-making skills.[7,8] * Most anesthesiology journals have not described decision-making processes in a systematic way, and we understand little about how decisions may be improved or harmed by cognitive factors.

The incidence of diagnostic error varies across physician specialty, with rates ranging from 2 to 12% in diagnostic radiology and pathology, 12 to 15% in emergency medicine,[9] and up to 50% with respect to diagnosing the cause of death.[10] Although the incidence of erroneous decision-making in anesthesiology is not known, reports from the American Society of Anesthesiologists closed claims registry suggest that more than half of diagnosis-related adverse events in obstetric anesthesia were related to a *delay* in diagnosis or treatment.[11] Most decision researchers believe that specialties characterized by a high degree of time pressure, data uncertainty,

stress, and distractors may have an even greater incidence of errors.[12] In some estimates, more than two thirds of missed or delayed diagnoses are caused in part by cognitive errors in decision-making.[13]

In principle, medical decision-making should be relatively straightforward. A constellation of clinical findings should generate a limited differential of known clinical conditions, ordered by their probability of occurrence. Diagnostic tests or responses to empiric therapy would then refine the list until only a few candidates exist with (usually) a clear favorite.

Abundant evidence, however, suggests that real-world medical decision-making is beset with variability and complexity. Physicians often fail to agree on the interpretation of diagnostic test results,[14–16] are inconsistent in their approach to management,[17–19] and arrive at different diagnoses in the presence of identical information.[13] Even for clinical conditions with a widely accepted theoretical framework and established diagnostic and therapeutic strategies, a startling amount of unexplained practice variability exists.[20]

Noncompliance with evidence-based guidelines developed by expert panels is high,[5] further highlighting the need

to understand physician decision-making. Noncompliance observed in simulated preoperative evaluation by anesthesiology trainees and experts shows the need to assess *decision behavior* in addition to medical knowledge.[21,22]

Although characteristics of human decision behavior have been studied in economics, business, and psychology, the extent to which anesthesia care is affected by cognitive decision errors is not known. It is also unclear whether key perioperative anesthesia decisions may be improved by application of human decision research from outside disciplines. Importantly, nonrational decision factors should not be viewed as uniformly good or bad.

This review has three sections. First, this article highlights leading models of decision-making and explores bias, heuristic, and nonrational cognitive processes that impact them (fig. 1). Then, to illustrate how such nonrational factors may affect anesthesia practice, we will analyze several anesthesia-related decisions. Finally, we will describe strategies to help recognize and/or recover from decision-making errors.

Models of Decision-making

Expected Utility

The longest lived and most widely accepted formal model of rational decision-making is termed "expected utility" (EU).[23,24] Developed in the 17th century, the EU model argues that humans decide among a set of choices by calculating the expected benefit from each choice (multiplying the *probability* of the outcome resulting from each choice by the *payoff* for that outcome) and selecting the option with the highest "expected value" (EV). As an illustration, consider a choice between two gambles involving a coin toss. The first would pay $2 for getting "heads" but nothing for "tails." The second would pay $1 for heads and $0.50 for tails. The first gamble would thus have an (EV) = 0.5 × $2 + 0.5 × 0 or $1, and the second an EV = 0.5 × $1 + 0.5 × $0.50 or $0.75. According to EU theory, the human should choose the first gamble due to the larger EV. Note that EU theory assumes complete *probabilistic knowledge* of all potential choices, the *payoffs* associated with each choice, and a well-organized and *consistent ordering of preferences* for each payoff.

Because these assumptions rarely apply in most real-world settings, decision researchers rapidly realized that such a model would be unlikely to predict human behavior. In 1978 the economist Herbert Simon won a Nobel prize for proposing that humans instead followed a modified, "bounded" rationality wherein "good enough" solutions replaced optimal ones when the effort of obtaining information was significant, and measurable subgoals took the place of goals more difficult to assess.[25]

Because medical decisions often involve incomplete data and outcome uncertainty, EU theory may likewise have limited applicability in a clinical care setting.[26,27] Not only are all the possible solutions difficult to identify, but also are payoffs diverse and uncertain, and identifying tradeoffs in choosing the optimum payoff can be difficult. Moreover,

Fig. 1. Influences on decision-making and diagnostic error. A variety of nonrational factors (*i.e.*, factors not based purely in statistics or logic) influence decisions; these factors are themselves neither good nor bad. This figure highlights factors discussed in this review but is not comprehensive. Importantly, decisions may also utilize rational processes. This graphic is not intended to compare the proportion of cognitive effort or time that is rational compared with nonrational.

physicians and patients may vary in their ordering of preferred outcomes.[28]

Bayesian Probability

This decision-making model adapts EU theory to permit new information to change existing odds. Because clinical medicine follows a similar dynamic trajectory, Bayesian approaches have been advocated for medical decision strategies.[29] As with EU, a decision begins by constructing a list of initial decision possibilities with their relative likelihoods. Unlike EU, however, new information from diagnostic tests or therapeutic interventions is used to modify the initial probability of each decision possibility. In this way, the pretest probability of a disease and the results of diagnostic testing (or therapy) both affect subsequent assessments of disease probability. By using sequential testing and observing the results of therapy, physicians should eventually arrive at the correct diagnosis or decision.

Because of its similarity to clinical medical management, Bayesian approaches to decision-making are frequently cited as "evidence based" and are widely taught in medical school.[30] However, Bayesian analysis suffers from many of the same limitations as EU theory. Pretest and posttest probabilities may frequently be elusive for individual patients, test results and responses to therapy may be difficult to interpret, likelihood ratios may be unavailable, and patient preferences may differ.

Formalized Pattern-matching

This decision model, developed to cope with limited statistical information, is the classic "case conference" approach taught

in medical school, and leverages the remarkable human ability to identify by pattern-matching.[31,32] In this approach, physicians begin by aggregating clinical observations into groups to reduce their number. As an example, prolonged hypotension, lactic acidosis, and hepatic failure may be aggregated into a composite "feature" of the case (inadequate end-organ perfusion). Then, pattern-matching is used to identify features of the case, or "pivots" that stand out, are unique, or do not fit. In this example, a pivot might be "if hypoperfusion was sufficient to cause hepatic failure, why was renal function not affected?" Because a pivot is often unique and may itself trigger diagnostic possibilities, the clinician then uses pivots to temporarily ignore nonessential features, and construct a list of diagnostic possibilities (causes of primary liver failure). The list of possibilities is then pruned by identifying incompatible features ("because of the rapid onset, cirrhosis is unlikely"), diagnostic testing/response to initial therapy, and by further pattern-matching ("in most cases of hepatic artery thrombosis, pain is common"). Candidate diagnoses are compared and those that are poor matches are often dropped.

Although surprisingly effective, the "pattern-matching" approach makes extensive use of cognitive shortcuts in place of statistical logic. Pattern-matching is heavily dependent on a mental pattern library that may vary in extensiveness with clinical experience and differs between individuals. In addition, factors other than frequency of occurrence may affect physician estimates of likelihood. By relegating pretest (and posttest) probabilities to a minor role, the process of selecting from the final, pruned list of choices thus becomes statistically vulnerable to error.

Heuristics

Although Simon's "bounded rationality" explained some human behavior that failed to follow EU principles, many other examples of human decisions that systematically deviated from EU theory soon surfaced. In 1982 the psychologist Daniel Kahneman won a Nobel prize for the systematic identification and characterization of human decision behaviors that (under certain conditions) violated rational EU doctrine. Kahneman[33] theorized that these decision behaviors represented cognitive "shortcuts" used preferentially by humans to reduce the cognitive cost of decision-making. He termed these shortcuts *heuristics*.

Heuristics are used frequently in medicine with the goal of making decisions more quickly or efficiently, when attempting to solve very complex problems, or when complete information is not available.[34,35] An anesthesia example might be "I always check a preoperative potassium (K^+) level in patients on hemodialysis and treat if the K^+ is greater than 5.5 meq/l." Note that this heuristic simplifies preoperative evaluation by eliminating the need to individually determine which patients need a preoperative K^+ check or to assess which K^+ levels are appropriate for which procedures.

Similarly, a mild, transient fall in blood pressure with induction may not prompt an exhaustive differential diagnostic evaluation. Most anesthesiologists would instead agree that a heuristic of initially attributing the hypotension to anesthetic induction appropriately preserves attention for other important tasks. Decisions in anesthesia practice are not only complex and often rooted in uncertainty, but must frequently be made in stressful conditions, under time pressure, and with high stakes. For these reasons, heuristics may be useful to anesthesiologists by allowing attention to be effectively allocated and distributed.

Although heuristics are often effective at finding reasonable solutions with reduced decision effort, they may not always lead to optimal solutions, and can be misapplied or fooled, depending on contextual features. In a classic example, Tversky and Kahneman[36] described a meek, tidy man who loves books and asked whether he was more likely to be a salesman or librarian. Both undergraduates and graduates diagnosed him as a librarian, ignoring the statistical paucity of male librarians relative to male salesmen. In the induction/hypotension example above, if the anesthesiologist fails to notice a developing rash or bronchospasm related to anaphylaxis, the mental shortcut of attributing hypotension to anesthetic induction likewise can fail.

Three heuristics identified by Kahneman can lead to neglect of baseline incidence information in medicine. The first is demonstrated with Kahneman's librarian example. Termed the "representativeness" heuristic, this strategy triages diagnostic decisions based on resemblance to a mental model rather than statistical probability. In addition to misdiagnosis by the sheer strength of the pattern match (as in the librarian example), representativeness can also cause diagnosticians to ignore probabilistic logic:

Example 1:[37]

Which statement is more likely?

1. Mr. F has had one or more heart attacks.
2. Mr. F is over 55 yr old, and has had one or more heart attacks.

Answer 2 is clearly a smaller subset of answer 1, so statistically answer 1 is correct. But answer 2 more closely matches the mental image of a patient with a heart attack, and was chosen more frequently in studies of college and graduate students. An example of such a question in anesthesia practice might be:

Which is more common?

1. An acute decrease in end-tidal carbon dioxide (mmHg) on anesthesia induction.
2. A known deep venous thrombosis and acute decrease in end-tidal carbon dioxide (mmHg) on anesthesia induction.

The preference for using the representativeness heuristic over statistical reasoning is sufficiently strong such that humans will use it even when the statistically correct choice is readily apparent, as in Example 2:[38]:

• A group is composed of 70 engineers and 30 lawyers. One member of the group is 30 yr old, married, with no

children. He is skilled and motivated, and is likely to be quite successful in his field. He is well liked by his colleagues. What is the likelihood that he is an engineer?

Although the first sentence provides the correct answer, approximately 50% of college and graduate students chose a number other than 70%. For anesthesiologists, an example might be:

Mr. Smith is obese and has hyperlipidemia, hypertension, and a family history of heart disease. Is his likelihood of a perioperative major adverse cardiac event higher than normal?

(Note that none of the above descriptors are independently predictive of perioperative major adverse cardiac event.)[39,40]

The following vignette demonstrates how pattern-matching heuristics can lead to diagnostic error in anesthesia practice:

A gravida-5, para-4 postpartum woman gets out of bed on postoperative day 1 after her third cesarean section and becomes acutely hypotensive with shortness of breath. She is morbidly obese, has 1+ pitting edema on exam, and has refused her last three doses of subcutaneous heparin (including one that morning). She rapidly loses consciousness and progresses to pulseless electrical activity. She is given tissue plasminogen activator for a presumptive diagnosis of pulmonary embolus.

Although many anesthesiologists might choose pulmonary embolus as a more likely diagnosis than postpartum bleeding† statistically postpartum bleeding is 100 times more likely, even given the patient's pattern-matching features‡ (obesity and heparin refusal).[41,42] As well, her symptoms are consistent with both pulmonary embolus and significant blood loss. Of course, any particular patient may have any outcome, regardless of statistical estimates.

A second commonly applied heuristic in medicine[43] was named the "availability" heuristic by Kahneman and describes the tendency to equate the memorableness of an event with its likelihood of occurrence. Because a shark attack is vivid and memorable, for example, its occurrence may be judged more common than statistically predicted. In medicine, numerous factors may affect the memorableness of an event including a bad outcome, an emotional attachment to a patient, its resemblance to published case reports, and whether it was anticipated (among others). Experts and novices may be affected by the availability heuristic in slightly

different ways. For the expert, extensive clinical experience increases the likelihood of personally encountering a rare event. That event then becomes memorable because of its rarity, or because an associated adverse outcome generates a strong emotional impact. After experiencing massive bleeding during mediastinoscopy, for example, an anesthesiologist may insist on crossmatching blood for all subsequent mediastinoscopies despite a low statistical likelihood of bleeding requiring transfusion. For the novice, rare conditions may come easily to mind either because they are interesting, exciting, and novel or because they are easily recalled from classroom learning. For both expert and novice, high-visibility attention (Morbidity and Mortality Conferences, media coverage, or lawsuits), may lead to increased "memorableness" and perceived frequency without any change in real statistical likelihood.

A third heuristic that is less well studied in medicine but may also play a role in medical decision-making is the "anchoring" heuristic. Also first characterized by Tversky and Kahneman,[36] the anchoring heuristic notes that when humans make an initial estimate of a value or state, and adjust that estimate in response to new information, the initial estimate, or starting point, affects subsequent estimates. As an example, Tversky and Kahneman[36] found that asking students to guess the product of $8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1$ resulted in a higher estimate than asking another group to estimate the product $1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8$.

In medicine, anchoring bias may lead to failure to adjust initial prognoses based on later information[44,45] or failure to modify initial diagnoses due to new events.[35] An example of anchoring bias in anesthesia might be a failure to adequately appreciate blood loss during a case in which no bleeding is expected. Another example of anchoring may occur during difficult airway management when repeated instrumentation efforts cause the effectiveness of mask ventilation to deteriorate. Anchoring on the initial "easy mask" conditions may lead to delay in recognition that the patient's clinical status is changing.

Most physicians are probably familiar with the potential for decisional error due to the *availability heuristic*. The oft-quoted medical axiom, "*When you hear hoofbeats, think of horses, not zebras,*" is intended to counterbalance the availability heuristic by reminding the decider to consider pretest probability when ranking diagnostic possibilities. By remembering that common symptoms (hoofbeats) are usually caused by common diseases (horses), physicians may thus prioritize more common (rather than less common) diagnostic possibilities for specific symptoms.

Dual Process Reasoning

A more modern understanding of human decision behavior includes characteristics of both the EU and heuristic-driven decision models.[46,47] This hybrid model is called "dual process reasoning," and asserts that humans may toggle back and forth between an intuitive autonomous decision

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† The authors' combined experience in presenting this vignette at multiple venues across the United States is that about 75% of anesthesiologists select PE over the statistically more likely diagnosis of postpartum bleeding.

‡ Readers may note that in this obese patient who has refused heparin, the pretest risk of PE is much higher than baseline estimates. Obesity increases risk of PE (OR = 2.8), see BMJ 2009; 338:b388. But obesity also increases the risk of postpartum bleeding (OR = 2.25), (Am J Obstet Gynecol 2013;209:51.e1-6.) Use of heparin likewise alters risk of embolus. Guidelines for prophylaxis in surgical patients (Chest 2012; 141:e227S–77S) suggests a 40% reduction in PE—not nearly enough to overcome a 100:1 ratio in pretest probability.

strategy (also called "type I" processing; fig. 2) and a deliberate statistical/analytic strategy (called "type II").[48–50] Although the factors that govern which processing strategy is used for which decision are incompletely understood, decisions that must be made rapidly and involve nonquantifiable cues, high stakes, and uncertain data are likely to trigger type I-driven decision-making whereas decisions that do not involve time pressure and can be analyzed using quantifiable cues or data, are likely to induce type II approaches. Thus, life-saving decisions made under high-stakes conditions and time pressure may be more likely to trigger an intuitive strategy. Cognitive psychologists estimate that we spend a considerable amount of decision-making time in intuitive mode, and although deviations from purely rational processes may occur in either mode, they are less likely to be noticed by the thinking in the subconscious intuitive mode. Intuitive mode may include "hardwired" instincts or processes that are implicitly learned or learned *via* repetition. Some error prevention strategies discussed in Educational Strategies to Improve Decision-making attempt to cue a toggle between the intuitive mode and the analytic mode. Importantly, we must emphasize that intuitive processes themselves are not errors, and in fact lead to fast and accurate decisions much of the time.

Sensemaking

Another modern approach to understanding human decision behavior is to reframe analysis of decisions from discrete *choices* made by human deciders to a *dynamic situational assessment of contextual features*. This "sensemaking" approach argues that making a decision first requires an effort to understand the ongoing event, and that such an effort involves initial and evolving impressions, dynamic feedback, and attention shifting to identify and decipher pieces of information. Our early impressions bias and inform what we subsequently give attention to or discount. This regulation of attention, in turn, influences what we think, including the biases and heuristics we apply going forward. Sensemaking has been described as the "complex cognition of the experience of now and then," resulting in a "too-lateness of human understanding,"[51] and can be thought of as a way to link interpretation and choice.[52] It strives instead to better understand the *context from which the action resulted* and thus to facilitate the creation of better conditions for future decision-making.[53] The related phenomenon of *hindsight bias*[54,55] plays a large role in judgments on the appropriateness of medical care.[56] Once given information about the outcome, humans may interpret the preceding events in a different light, viewing outcomes as *more predictable* and actions as less correct. Although few studies currently link medical decision making and sensemaking, educational strategies may be used to disrupt the normal flow of sensemaking and more closely examine attentional focus, potential biases and heuristics that affect decision quality.

Cognitive Influences on Anesthesiology Decision-making

Many other cognitive, emotional, cultural, and environmental factors can also affect how anesthesiologists decide[57,58] (table 1). Although an exhaustive description of known decision modifiers is beyond this review, we will focus on decision

Fig. 2. Dual process model of reasoning: This illustrates how intuitive processes (type I) and analytical processes (type II) interact to influence diagnostic thinking. Some type I processes go directly to end decisions without any overrides, toggling, or calibration and represent largely unexamined decision-making. Explicit effort allows for toggling between type I and type II processes. Repetition of analytic processes until they *become* automatic is the basis of skill acquisition. This model does not account for proportion of time spent in, nor superiority of, one process over another. Error may be made in either system at any point, including the starting point (*i.e.*, patterns may be "recognized" incorrectly). (Adapted with permission from Croskerry P, Singhal G, Mamede S: Cognitive debiasing 1: Origins of bias and theory of debiasing. BMJ Qual Saf 2013; Oct; 22(suppl 2):ii58–64. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.)

Table 1. Nonrational Cognitive Factors that Influence Decision Making*

Cognitive Influence	Explanation
Representativeness heuristic	Diagnosing or identifying by the degree of resemblance to preexisting or "classic" mental models.
Availability heuristic	Diagnosing or identifying by resemblance to previous, highly memorable, events. "memorableness" may be induced by an emotionally charged past experience (usually negative); media attention, legal action, peer review "morbidity and mortality" conference, or other novelty.
Anchoring/fixation/"tunnel vision"	1. Insufficient adjustment from an initial assessment of a value or a state. "Anchoring" on the starting point can bias subsequent estimates. 2. Focus on a single feature of a case or event exclusively, at the expense of considering other aspects of the case. This may include task fixation, such as troubleshooting of an alarm at the expense of maintaining situation awareness.
Retrospective biases	Tendency to view events that have already occurred differently once the outcome is known. 1. Hindsight bias: Tendency to view events as having been more *predictable*, and thus actions more correct or incorrect, than was apparent as the situation was unfolding. 2. Outcome bias: Favorable (if the outcome is good) or unfavorable (if the outcome is bad) assessments of judgments, *regardless of actual decision quality.* (Example: drunk driver who arrives home safely rationalizes that he made a "good choice" - which is obviously incorrect!)
Confirmation bias	A tendency toward only seeking (or only "seeing") information that supports a diagnosis or hypothesis, rather than information that refutes it.
Visceral (transference) bias	*Visceral bias* describes the tendency to allow feelings about a patient to affect care decisions, as with a "VIP patient," a victim of trauma, or a "high-maintenance" patient.
Omission bias	Tendency toward inaction rather than action, out of fear of causing harm (to patient, if action failed; to self, by damaging professional reputation if wrong). May be especially likely when a significant authority gradient is perceived or real.
Bias blind spot	A flawed sense of invulnerability to bias; may be more prominent among cognitively sophisticated and highly intelligent.
Overconfidence	Inaccurately high self-assessment with regard to positive traits. Can refer to medical knowledge, certainty regarding diagnosis, technical abilities, and situational assessment.
Memory shifting/ reconstruction	Failure to accurately recall information. Occurs due to meaning and verbatim information being coded differently, and results in "filling in" details (sometimes misinformation) when memories are recalled. Also called "memory reconstruction error."
Preference for certainty	Human preference for certainty over risk, even at the expense of sacrificing a greater *expected value* (*i.e.*, calculated *via* expected utility theory).
Framing	A schema of interpretation that changes perception without altering facts. *Equivalence framing* refers to the interpretation of the same set of data as either a gain or loss. *Emphasis framing* focuses on a subset of selected data to match an event or explanation.
Loss aversion	Tendency for humans to view a loss as significantly more psychologically powerful than a gain of the same amount.
Affect (emotion) Anger Regret	Emotional influences on decision behavior. *Anger* describes the tendency for angry or disruptive behavior to influence the decisions of oneself or others. *Regret* describes the tendency to allow regret for previous decisions to affect future ones. *Anticipated regret* is the desire to avoid regret from future consequences or outcomes of decision choices.
Feedback bias	Significant time elapses between actions and consequences; lack of outcome data reporting. Absence of feedback is subconsciously processed as positive feedback.
Commission bias	Tendency toward action rather than inaction, even when those actions are unindicated or founded on desperation. This is the "better safe than sorry" mentality of adding additional invasive monitors, central venous access, or liberal blood transfusion. Backfires when those actions have untoward effects.

* Factors are presented in order of their appearance in the text; table is not intended to be exhaustive.

VIP = "very important person" as with a celebrity, personal friend, or high-level executive.

factors that have been studied in medical domains, including bias, overconfidence, memory error and hindsight, preferences for certainty, framing, loss aversion, and emotion (affect).

Bias and the "Bias Blind Spot"

A decision-making "bias" refers to a systematic preference to exclude certain perspectives on decision possibilities. Biases may result from subconscious influences from life experiences and individual preferences, and can affect medical decision-making in both conscious and unconscious ways. An example of bias in anesthesia practice might include the following statement: "I usually do not perform awake fiberoptic intubation on teenagers because it is too traumatizing to the patient." The perspective reflected in this statement excludes the possibility that awake fiberoptic intubation may not always be traumatizing, and may be tolerated by some teenagers, and also unintentionally prioritizes the avoidance of such trauma over the safety of the patient.

Confirmation bias, which describes the tendency to only seek or recognize information that supports a diagnosis or hypothesis, rather than information that refutes it has been extensively demonstrated in scientific fields such as forensic analysis[59] and also in medicine.[60] In one study, tanned skin was interpreted more often as jaundice when residents were

biased toward liver cancer than stomach cancer.[61] It is easy to see how confirmation bias may lead to diagnostic error in medicine. In anesthesia practice, examples of confirmation bias might include focusing on reassuring features of an easy airway, rather than exhaustively seeking evidence to indicate difficulty might be encountered.

A second bias potentially relevant to anesthesia practice is *visceral (transference) bias*. This bias describes the effect of negative or positive feelings about a patient on diagnostic or management decisions. Examples of visceral bias suggest that patients with unusual sociocultural attributes may get treated differently than "regular" patients.[62,63] Examples of visceral bias in anesthesia may include any deviation from usual practice for a "very important person," such as a different transfusion threshold, or an insistence that the attending personally perform all procedures.

A third bias, termed omission bias, describes a tendency toward inaction (and preserving the *status quo*) over action even when acting to change the current state is objectively better. For example, studies suggest that people given too much change are more likely to keep the extra money (inaction) than they are to steal an equivalent amount (action).[64] Omission bias is well described in medicine[65] and usually involves a psychological hurdle that must be overcome. This hurdle may be rooted in fear of harm, either of the patient in the case of a dramatic maneuver gone awry, or harm to the professional reputation if the anesthesiologist is wrong or appears incompetent. An example in anesthesia might be hesitating to initiate a surgical airway when routine airway management fails and the patient is deteriorating. Omission bias is also a possible contributor when team members fail to "speak up" about an important clinical or safety issue.

Although such biases can clearly affect decision behavior, consciously believing oneself to be impervious to bias can also affect decision behavior. Cognitive psychologists call this false sense of invulnerability from bias a "bias blind spot."[66] Interestingly, bias-induced effects on decision-making appear correlated to cognitive ability, as the bias blind spot is more prominent among individuals with greater "cognitive sophistication."[67]

Overconfidence

An abundance of research in social science domains suggests that humans are prone to inaccurately high self-assessment with respect to desirable attributes such as ethics, productivity, rationality, intelligence, and health.[68] This inappropriate tendency toward overconfidence occurs in both medical and nonmedical fields, in more than 90% of professors,[69] and in physicians who are demonstrably inaccurate in self-assessment[70] and accuracy of diagnosis.[10,71]

Overconfidence may adversely affect decision-making in two ways.[7] First, unwarranted diagnostic confidence may prevent consideration of other diagnoses and lead to *premature closure* of the diagnostic process. In addition, overconfidence in technical or diagnostic abilities may delay physicians from calling for help, prevent them from recognizing a medical error, or cause them to choose less safe care strategies. For anesthesiologists, struggling with a difficult airway and being unwilling to call for help may be an example.

Finally, overconfidence may prevent individuals from adopting safety practices developed by others.[72] An example in anesthesia might be a reluctance to adopt ultrasound guidance for central line insertion despite considerable evidentiary support and guideline recommendations. Paradoxically, overconfidence may be difficult to modify, as more than half of people believe themselves to be above average at accurate self-assessment,[65] and may thus not be able to recognize overconfidence in themselves.

Memory Shifting (Reconstructed Memory Error)

Humans generally accept that memories are imperfect because most have experienced forgetting something altogether (such as a phone number). However, existing evidence suggests that the actual remembered content of events can also be flawed. Fuzzy trace theory suggests that humans store some verbatim information as discrete data values, but store experiences differently, encoding the meaning of the experience rather than the exact events.[49,73,74] The act of "remembering" thus requires a process where details that were forgotten or never stored are "filled in" by partially true or even false information created to conform to the present narrative (fig. 3). Memories may therefore be inherently dynamic and vulnerable to disruption.[73] An "everyday" illustration of this phenomenon is well described in the legal system, with the unreliability of eyewitness reports.[75] An example in anesthesia practice might involve two physicians honestly recalling the details of an emergency event differently, or the certainty of recalling that a patient's blood pressure remained above a certain threshold during a hemorrhagic event, when in fact it had fallen below that threshold.

Preferences for Certainty

Among the first critiques of the EU model was the finding that EU decision analyses failed to predict human preferences for certainty. The French economist Maurice Allais[76] created the first and most famous example:

Consider the following choices with equivalent EVs:

A: Eighty-nine percent chance of $1 million, 11% chance of 1 million ($1 million for sure);

B: Eighty-nine percent chance of $1 million, 10% chance of $5 million, and 1% chance of nothing.

Most would choose the guaranteed $1 million represented by A. But when given a related set of choices:

C: Eighty-nine percent chance of nothing, 11% chance of $1 million and

D: Ninety percent chance of nothing, 10% chance of $5 million,

most would choose D.
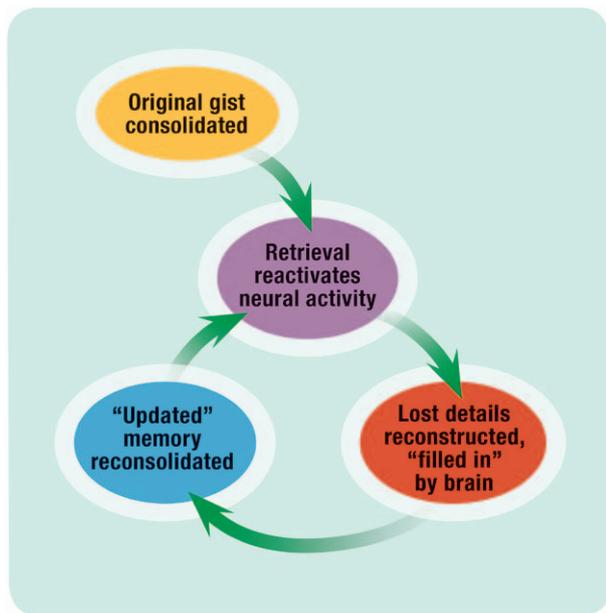
Fig. 3. Memory reconstruction error (also called "retrieval-induced distortion"). Neural processes are dynamic and vulnerable to disruption during reactivation. Information may be lost, and misinformation may be incorporated into memory, which is subsequently reconsolidated and stored *in lieu* of the original memory. This perpetuates with each memory reactivation, which is a necessary part of recollection. Note that this process is distinct from intentional distortion of the facts.

Allais argued that these preferences contradicted EU theory. He noted that in the first pair (A or B), most choose A even though choice B provides a higher EV. To show the decision was not due to the order of choices or wording, Allais created the second pair of choices (choices with identical EVs, differing only in the degree of certainty) and showed that when greater certainty was not a decision factor people chose the higher EV (D).

The human desire for certainty clearly violates EU-based choice algorithms but reflects deeply held preferences about risk avoidance. An example in anesthesia might be the preoperative potassium decision presented earlier. Statistically, the combination of potassium measurement error, intraoperative tolerance for abnormal potassium levels, and likelihood of a dangerously abnormal preoperative potassium level in a hemodialysis patient makes it unlikely that such a test will have therapeutic implications. Yet many practices routinely check a preoperative potassium level, in part because they value the certainty of knowing the level before inducing anesthesia.

Framing and Loss Aversion

One of the strongest demonstrable biases in human decision-making is the preference to behave differently depending on whether the decision is viewed as a gain or a loss. This "framing" effect was first characterized by Tversky and Kahneman[77] in 1981, with their now famous "Asian disease"

problem. Asked to choose between two treatments for a disease expected to kill 600 people:

- Treatment A: 200 people will be saved
- Treatment B: there is a one third probability that 600 people will be saved, and two thirds probability that no people will be saved

a majority of subjects chose A. However, when a second group of subjects were presented with a different formulation of the two choices:

- Treatment C: 400 people will die
- Treatment D: There is a one third probability that nobody will die, and two thirds probability that 600 people will die

participants chose D. Note that both choice pairs are identical, but A and B are framed as gains (people saved) whereas C and D are framed as losses (people dead). Kahneman found that nearly all humans will choose the less risky option when the choice was framed as a gain, but the more risky option when the choice was framed as a loss.

Because many choices in medical care can be framed as gains or losses, this preference can easily affect patient and physician choices and contribute to decision diversity.[78] Framing may play a role in anesthesia practice in decisions to delay or cancel cases where optimization is imperfect. For a patient with lung cancer and severe symptomatic hypothyroidism, for example, delaying the lobectomy allows the hypothyroid condition to be treated, reducing the risk of life-threatening complications, but increasing the risk of metastasis. Framing the case as a chance to cure cancer *versus* the chance of an adverse intraoperative cardiorespiratory event may result in different decisions. In addition to viewing choices as losses or gains (*equivalence framing*), framing may also be used to focus thinking on a subset of data or choices to match an explanation (*emphasis framing*), as with the obstetric pulmonary embolus *versus* hemorrhage vignette.

Another powerful framing effect, also first identified by Kahneman and Tversky, is a stronger preference to avoid a loss compared with the desire for a similarly sized gain. This preference, termed "loss aversion," can cause negative associations from a loss to be twice as powerful as positive associations from an equivalent gain.[79] In medicine, losses may take a variety of forms, including physical harm to a patient, perceived loss of reputation if a physician makes an error, and possibly even loss of licensure. In perioperative care, loss aversion may affect decision behavior by causing physicians to modify operative timing in subsequent patients[80] or change thresholds for withdrawal of life support.[81]

Affect (Emotion)

Most theories of human decision behavior focus on information processing. However, emotional responses to stimuli
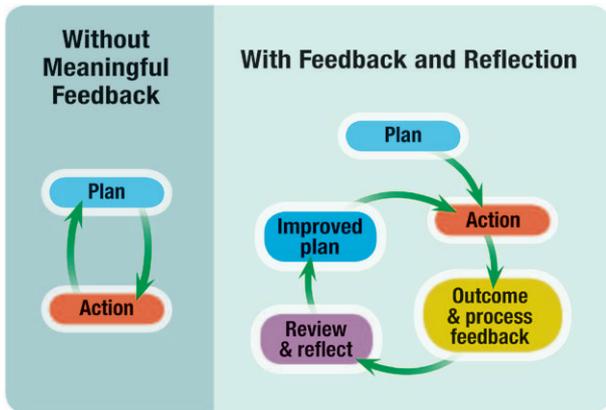
Fig. 4. Feedback bias illustration. Timely and specific feedback about both outcome and processes is required for reflection and ongoing practice improvement. The mindset that "no news is good news" contributes to lack of reflection and practice improvement, and reinforces overconfidence.

often occur before conscious analysis and can affect decisions in nonmedical contexts.[82] Although the role of emotion in medical decision-making is poorly studied, current evidence suggests that at least two emotions may significantly modify medical decisions.

The first of these is *anger*. Abundant evidence links anger to disruptive behavior by healthcare providers,[83] and demonstrates that anger prevents effective communication between perioperative care providers.[84] Caregiver perceptions also associate disruptive behavior with medical errors.[85]

Regret is also a likely modifier of physician decisions. In a choice context, regret requires two distinct components: a wish that one had chosen differently and self-blame for not having done so.[86,87] Clearly, regret-based decision-making is nonrational. Not only does it not account for probabilities or payoffs, different people may regret different things, and to variable degrees. Moreover, regret may depend on events that occur after the decision. A person who buys a house, for example, may regret the purchase if a fire destroys the house several months later. Regret can affect medical decisions in two ways. First, physicians experiencing a bad outcome as a result of a specific decision may be less likely to make that same decision in the future.[80] In addition, decisions may be influenced by *anticipatory regret*—the desire to avoid regret related to the consequence or outcome of a decision.[88]

As with preferences for certainty, regret is a nonrational but a strong influence on human decision behavior in medicine. One possible reason for use of regret in clinical medicine may be that it allows a readily accessible decision tool for circumstances where adequate statistical information is unavailable. Under such circumstances, decision options may be ordered by their degree of anticipatory regret and the option that results in the least regret chosen.

Feedback Bias

Although incomplete feedback may disadvantage learners by failing to address underlying rationales, absent feedback may also distort decision behavior (fig. 4). Because many anesthesiologists lose contact with their patients after they leave the postanesthesia care unit, feedback on anesthesia-related outcomes such as nausea and vomiting, pain, recall, neuropathy or eye injury from inadequate protection, myocardial infarction, and death is often incomplete. Given the absence of routine feedback, anesthesia caregivers may assume everything went well, and thus fail to adequately calibrate themselves to true event incidences. This "feedback bias" may be one reason why survey-based estimates of recall under anesthesia are considerably lower than those based on directly measuring recall.[89]

An Example of Decision Factors at Work in Anesthesia: An Airway Vignette

Because so few decisions in medicine have rigorous statistical support, and because so many cognitive and emotional factors may affect human decision behavior, physicians' choices are rarely purely statistically based. The following example will illustrate how many of the aforementioned factors can influence a familiar series of decisions in airway management. Note that because this vignette represents real-life decision-making, the use of nonrational decision factors is not necessarily incorrect or inappropriate. A sweet and shy 14-yr-old girl presents for a small inguinal hernia repair. She has a history of a severe sore throat and chipped tooth after an emergency appendectomy at an outside hospital, but has no external indicators of a difficult airway and was not told anything about her previous anesthetic. You perform the American Society of Anesthesiologists guideline–recommended 11-point airway exam,[90] and in her case, all elements are normal except for a highly arched, narrow palate. Because no specific algorithm exists to convert her "1 out of 11" score into a meaningful prediction of difficult ventilation or intubation, you switch to an intuitive "gut" analysis (*dual process*). Is the airway truly difficult? It does not look like it to you (*representativeness*), and she has no medical alert bracelet or letter (*confirmation bias*). Moreover, you have always been able to intubate even when the laryngoscopic view is not good (*overconfidence*). However, you recall hearing about a patient just like this one several years ago who needed a tracheostomy when a colleague on call could not intubate or ventilate. It was a big deal at grand rounds (*availability*). You briefly consider an awake fiberoptic bronchoscopy, but the patient is so young, and you hate to subject her to the unpleasantness of that procedure (*visceral bias*). You again ask her to open her mouth and feel reassured that, aside from the palate, the rest of the airway exam is normal; (*confirmation bias*). You proceed with induction, feeling pretty sure you will be able to ventilate at least, and knowing that you can get a glidescope if you need it (*overconfidence*). As she says goodbye to her parents and you roll back to the operating room, you briefly question your decision, thinking about how bad you will feel if you have an airway catastrophe (*regret, loss aversion*) and wondering whether you should just use the fiberoptic approach to make sure you do not lose the airway (*preference for certainty*). The chain of thought is quickly lost as the surgeon reminds you that he has a

long list of cases to do today and urges you to go ahead. "It will take you longer to get the airway than it will for me to do the surgery!" he jokes. Also, because you have not done many awake fiberoptic intubations recently, you worry you might appear incompetent if it is not smooth (*loss aversion*). You proceed to induce anesthesia and attempt mask ventilation. Even though you cannot ventilate easily, you figure that paralysis will improve mask ventilation as it often does (*representativeness*), so you give muscle relaxant. Your first laryngoscopy reveals a grade 4 view and you attempt external laryngeal manipulation to improve the view. After 10 to 15 s, the nurse asks if you need a hand, but you say nothing, persisting with your laryngoscopy and certain that if you can just move the larynx 1 mm more, you will be able to see (*anchoring, overconfidence*). The patient starts to desaturate, but you are focused on the task and just need a few more seconds (*anchoring*). The nurse points out that the patient looks dusky, which gets your attention, and you retry mask ventilation. However, it is now apparent that you cannot move air. You know you could ventilate before, and cannot believe you cannot ventilate now (*anchoring, overconfidence*). You place a laryngeal mask with some difficulty, but still cannot ventilate. After another failed laryngoscopy, you attempt a blind intubation with the bougie. You briefly consider asking for a tracheostomy tray but a surgical airway is so dire, and performing a tracheostomy on this young girl will surely get you sued, so the thought is quickly replaced with the hope that the glidescope will arrive soon (*omission bias, framing a surgical airway as "bad" instead of life-saving*). The heart rate now slows to 35 beats/min and you see wide QRS complexes on the electrocardiogram. Fortunately, you are able to place the bougie and intubate successfully. She stabilizes, the procedure is cancelled, and luckily, she wakes up without any neurologic deficit. You are devastated, relieved, and vow to have a lower threshold for performing awake fiberoptic intubations on patients in the future; this is a hard lesson you will never forget (*availability bias*). The surgeon reassures you, noting: "After all, all's well that ends well!" (*outcome bias*). Your colleagues, however, are incredulous that you would have even considered an asleep intubation, given her history (*hindsight bias*).

Educational Strategies to Improve Decision-making

For many decisions in medicine, an optimal choice is not clear. Individual preferences, bias, framing effects, cost, and other factors may all alter perceived decision quality, yet error persists. Self-awareness of human cognitive processes and their potential pitfalls may help improve deliberate thinking strategies (a process called *metacognition*). This section will describe educational or practice interventions that have been advocated for raising self-awareness of cognitive processes.

Educational Strategies
Targeting Rationale Instead of Behavior. Developing expertise requires not only experience but also timely and specific feedback on decisions and behaviors.[12,91] As Rudolph[92] describes, effective feedback hinges not only on observing and correcting incorrect behaviors, but also on understanding how the learner perceives his or her decisions. In our view, all behaviors may be classified using a 2 × 2 table (table 2), where desired actions and undesired actions are crossed with appropriate or inappropriate rationales. Actions (behaviors) may thus be subclassified into the right action for the right reason, the right action for the wrong reason, the wrong action for the right reason, and the wrong action for the wrong reason. An example would be if a trainee administers oxygen to a patient before anesthetic induction (correct) but believes that the rationale is to increase the patient's oxygen saturation (incorrect). Without specific probe into the rationale, no apparent error is detectable. Both overt performance gaps (actions) and incorrect rationales are important educational targets because an incorrect rationale may lead to future mistakes in related but different situations.

Metacognition (Self-reflection and Reflective Practice). *Metacognition*, or "thinking about thinking," describes the process of reflecting on one's own thought process and decision-making behavior.[93–96] Although better studied in nonmedical domains, increasing insight into decision-making tendencies may improve awareness of decision processes at high risk for medical error.[12,57,93,94] Reflective physicians may be more likely to recognize deviations from rational thought processes, and engage in strategies to clarify and/or support their thinking. Approaches such as explicitly testing assumptions, slowing down (to engage in deliberate cognitive processes), seeking alternative explanations, and accepting uncertainty are examples of metacognition and reflective practice.[97,98]

Table 2. Behaviors, Rationales, and Educational Targets

Behavior/Rationale	Example	Educational Target
Right behavior, sound rationale	Preoxygenate to increase oxygen reservoir in lungs and delay desaturation with anesthetic-induced apnea	Positive reinforcement of correct behavior and rationale
Right behavior, flawed rationale (accident, coincidence)	Preoxygenate before induction to "achieve 100% oxygen saturation"	Correction of flawed logic, discussion of preoxygenation purpose
Wrong behavior, sound rationale (slip or lapse)	Intend to preoxygenate, understands correct rationale, but forget to increase oxygen flowmeter	Discussion of memory aids or other methods to maintain situation awareness, check all essential items before beginning a procedure, *etc.*
Wrong behavior, flawed rationale (mistake)	Neglect to preoxygenate before induction "because patients consume less oxygen under anesthesia"	Discussion of respiratory physiology and effects of anesthesia

Clinical Aids

Cognitive Self-monitoring Strategies. Cognitive self-monitoring strategies (sometimes called "cognitive forcing strategies" or "debiasing strategies") are attempts to minimize influences of nonrational decision preferences by creating rules to induce self-monitoring of decision-making processes.[98,99]

Such strategies require both a *reasoning process* and a *trigger* that signals clinicians to recognize and rescue themselves from the error.[100] One such strategy in anesthesiology is the "rule of three."[58] This strategy requires that the anesthesiologist consider at least three alternative explanations before a diagnosis may be accepted, and requires a reassessment of the diagnosis if the first three treatment maneuvers do not produce the expected response. Another is that of "prospective hindsight"—widely used in military strategy—in which the physician imagines a future in which his or her decision is wrong, and then answers the question "What did I miss?"[101]

Two additional self-monitoring strategies exist to prevent a focus on obvious or statistically likely diagnoses from itself triggering an anchoring heuristic. The emergency room/trauma axiom "the most commonly missed injury in the emergency room is the second," is an example intended to help physicians avoid fixation or tunnel vision error by conducting a thorough secondary survey, regardless of the primary or most obvious injury. Additionally, the "rule out worst case" approach to diagnosis is intended to ensure the consideration of statistically rare but very significant diagnoses.[12]

Certain conditions may predispose to biased or nonrational decision processes. Clinicians may increase their self-monitoring of these vulnerabilities by asking questions such as (adapted from Graber, *via* personal communication§):

- Was the diagnosis suggested to me by the patient, nurse, or a colleague?
- Did I accept this patient as a "hand-off" from a previous caregiver?
- Did I consider organ systems besides the obvious one?
- Is this a patient I do not like, or like too much, for any reason?
- Have I been interrupted or distracted while caring for this patient?
- Am I cognitively overloaded right now?
- Am I stereotyping the patient or the presentation?

Decision Support. External decision support tools are also effective ways to reduce effects of nonrational cognitive factors. These tools are commonly used in aviation and include checklists, written algorithms, clinical decision aids built into electronic medical records, and guidelines. Intended to

decrease omission of important steps in complex procedures, checklists have gained popularity in medicine and improved task performance in perioperative care settings.[102] Checklists and similar algorithmic cognitive aids, particularly when managed by a caregiver ("reader") whose explicit task is limited to ensuring the algorithm is followed, are increasingly popular as decision support tools for critical events in the operating room.[103–105] Use of such aids may be effective in promoting better decisions and mitigating the influence of nonrational cognitive factors presented in this review and in table 1. Decision aids built into electronic medical records may also help physicians guard against nonrational cognitive influences. Existing studies, however, are mixed regarding their effectiveness at improving care.[106,107] Among the possible explanations for this counterintuitive finding are the poor clinical validity of decision aids, the large amount of "copy and pasted" information in electronic medical records, alert fatigue, and poor physician compliance.

Clinical practice guidelines are another strategy to better align medical decision-making with published evidence. Generated most commonly by expert panels convened by specialty societies, practice guidelines are intended to improve decision behavior both by providing an up-to-date literature review and by offering a "best practice" strategy. For anesthesiologists, the American Society of Anesthesiologists Webpage on standards and guidelines contains 11 guidelines, 5 standards, and 31 statements at the time of writing this article.

Conclusion

A recent focus on strategies to reduce medical error has led to greater academic and societal interest in medical decision-making. Observations that physician decision behavior is highly variable and often statistically unsupported have raised the possibility that improving physician decision-making may reduce medical errors and improve the quality of healthcare delivery.

In principle, a "correct" decision is logically consistent, statistically correct, and considers all available options. In medicine, however, a single correct decision is often difficult to identify. Patient and physician preferences, diagnostic and therapeutic uncertainty, and a wide variety of decision factors, may all complicate identification of the "best" decision. Even when viewed retrospectively, decisions may be difficult to evaluate, as hindsight bias may cause reasonable decisions to be judged harshly if they result in a poor outcome.

Although classic models of decision-making in medicine are rooted in logic and probability, evidence shows that real-world medical decision-making is frequently driven by the use of cognitive shortcuts, individual preferences, emotions, and an experience base distorted by imperfect recall and inaccurate estimates of likelihood. Although unproven, it seems reasonable that increasing awareness both of intuitive or autonomous decision processes and of statistically driven

§ Graber ML. *via* e-mail communication on September 30, 2013. Unpublished work related to: Checklists to reduce diagnostic error in emergency medicine. AHRQ ACTION 1 Contract Task Order #8 to RTI International: Develop Patient Safety Interventions to Reduce Diagnostic Error in the Ambulatory Setting. AHRQ Contract Number HHSA2902006600001I, 2010.

approaches where possible may improve both the accuracy and consistency of medical decisions.

No evidence exists to unequivocally support routine application of strategies for modifying or increasing awareness of nonrational decision factors. Nevertheless, without self-awareness of how humans make decisions, modifying decision behavior is likely to be difficult. Strategies for improving such self-awareness might begin with educating physicians with respect to the diversity of decision factors currently used in medicine. Explicit teaching about mechanisms of cognition and common errors that result could then be prioritized from the beginning of medical school. Strategies to rapidly recognize and recover from these errors could likewise be taught in medical school, throughout residency, and in continuing medical education. Understanding that framing effects alter the willingness to gamble, for example, may allow physicians to explore their own decision consistency by reconsidering the decision with a different frame. Other cognitive strategies that have been used effectively include counterbalancing heuristics or rules of thumb and forcing strategies where specific conditions trigger a "decision timeout" to make sure that relevant items have been considered. Finally, improving feedback, providing evidence-based guidelines, and increasing access to statistical tools and clinical decision support are other strategies that may raise awareness of decision factors and may improve decision behavior. More research is needed to evaluate the impact of these strategies on clinical outcomes.

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Competing Interests

The authors declare no competing interests.

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