How People Make Decisions That Involve Risk

A Dual-Processes Approach

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ABSTRACT—*Many health and safety problems, including war and terrorism, are by-products of how people reason about risk. I describe a new approach to reasoning about risk that implements a modern dual-process model of memory called fuzzy-trace theory. This approach posits encoding of both verbatim and gist representations, with reliance on the latter whenever possible; dependence of reasoning on retrieval cues that access stored values and principles; and vulnerability of reasoning to processing interference from overlapping classes of events, which causes denominator neglect in risk or probability judgments. These simple principles explain classic and new findings, for example, the finding that people overestimate small risks but ignore very small risks. Fuzzy-trace theory differs from other dual-process approaches to reasoning in that it places intuition at the apex of development, considering fuzzy intuitive processing more advanced than precise computational processing (e.g., trading off risks and rewards). The theory supplies a conception of rationality that distinguishes degrees of severity of errors in reasoning. It also includes a mechanism for achieving consistency in reasoning, a hallmark of rationality, by explaining how a person can treat superficially different reasoning problems in the same way if the problems share an underlying gist.*

KEYWORDS—*risk perception; risky decision making; fuzzy-trace theory; intuition; dual processes in reasoning*

As I write these words, coalition troops are at war in Iraq. The decision to go to war with Iraq, like many decisions, was based on a perception of *risk*, that is, the perceived threat posed by Iraq under Saddam Hussein. Key government officials also believed that inaction with respect to Iraq posed a greater risk than taking action. Since September 11, 2001, foreign threats and risks of terrorism have loomed large in people's perception, dwarfing perennial killers such as highway accidents and heart disease. In this article, I discuss the psychological factors that shape the perception of many kinds of risks and the decisions that involve those risks.

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A SHORT HISTORY OF RESEARCH ON MEMORY AND REASONING

In the following section, I outline recent advances in research on the psychology of risk, drawing on modern concepts of memory representation, retrieval, and processing. New ideas about dual processes in memory and reasoning make it possible to predict risk perceptions and decisions that involve risks, rather than merely explain them after the fact. Before proceeding, however, it is useful to discuss the background of research on memory and reasoning, which led up to these new developments regarding risk.

The conception of memory that has dominated psychology for decades is the computer metaphor. That is, information is considered to be held in a temporary store, called *working memory*, that has limited capacity. The idea that working memory has a limited capacity goes back to George Miller's research on the "magical" number seven (the number of chunks of information that he estimated could be processed at one time). Miller's work influenced many psychologists, notably Herbert Simon, who was a pioneer in research on judgment and decision making. Relying on the assumption that working memory was limited, Simon introduced the concept of *bounded* rationality. In short, Simon thought that human rationality is limited because of limitations in human information processing.

The assumption that human information processing is limited continued to be the main motivating assumption behind subsequent approaches to judgment and decision making, including both heuristics-and-biases and fast-and-frugal approaches (see Gilovich, Griffin, & Kahneman, 2002). According to these views, humans use heuristics or fast-and-frugal reasoning strategies as mental shortcuts because of information processing limitations. The need to conserve limited mental resources was seen as the driving force in reasoning, judgment, and decision making.

Although the computer metaphor guided research for decades, it has recently come under attack. Memory researchers have begun to criticize the concept of limited capacity in working memory (Nairne, 2002). Moreover, evidence indicates that working memory capacity is unrelated to the accuracy of reasoning, judgment, and decision making. Researchers have studied many tasks, and each has shown the same result: Reasoning is independent of memory (Reyna & Brainerd, 1995). In addition, researchers have noted that dramatic errors in reasoning occur on tasks that impose few demands on memory capacity (Shafir & LeBoeuf, 2002).

These findings of independence between reasoning and remembering prompted the development of fuzzy-trace theory (Reyna & Brainerd, 1995). Fuzzy-trace theory accounts for this independence through the assumption that people form two kinds of mental representations, verbatim and gist representations, but rely primarily on gist. Gist representations are fuzzy (less precise than verbatim representations) traces of experience in memory, hence the name fuzzy-trace theory. Because two kinds of representations are posited, fuzzy-trace theory is an example of a dual-process model of memory.

Fuzzy-trace theory explains findings of reasoning-remembering independence because responses to memory tests often require the details found in verbatim representations, whereas responses to reasoning tests often require only gist representations. Thus, reasoning accuracy is independent of memory accuracy because gist representations are independent of verbatim representations. This explanation was confirmed by experiments in which the reliance on verbatim versus gist representations was actively manipulated (e.g., through instructions or by varying the time delay prior to the memory test), producing positive dependency, negative dependency, and independence between memory and reasoning under theoretically predicted conditions (Reyna & Brainerd, 1995). Finally, assumptions of fuzzy-trace theory have been modeled mathematically to secure quantitative estimates of the contributions of verbatim and gist representations, and associated judgment processes, in a variety of tasks (Reyna, Lloyd, & Brainerd, 2003).

Fuzzy-trace theory is a dual-process theory of reasoning as well as memory. People can use either verbatim or gist representations to solve reasoning problems (although they mainly use gist). Researchers who study fuzzy-trace theory treat judgment-and-decision-making tasks as examples of reasoning problems, but work from a conception of reasoning that is different from traditional approaches. Traditional theories of reasoning are modeled on logic or computation; reasoning is said to occur in a series of ordered steps (e.g., premises are first understood and then integrated to draw conclusions), and precision is considered a hallmark of good reasoning. In contrast, according to fuzzy-trace theory, reasoning processes unfold in parallel rather than in series, often operating on the barest senses of ideas (the gist of a problem), and are fuzzy or qualitative rather than precise. Thus, a person presented with a reasoning problem encodes multiple representations of the same problem facts, retrieves reasoning principles from his or her stored knowledge (e.g., the principle that probability depends on the number of wins out of the total number of plays), and applies the reasoning principles to the mental representations of the problem facts. In this view, human reasoning is a messy process: Multiple perceptions of the problem are encoded, the right reasoning principle might or might not be retrieved, and the execution of processing (applying principles to problem representations) is unreliable. Processing is considered to be unreliable because of interference (getting bogged down in the execution of processing; discussed in the next section), as opposed to logical incompetence or memory overload.

Fuzzy-trace theory differs from other dual-process approaches to reasoning in some important respects. One example of these differences is that fuzzy-trace theorists place intuition at the apex of development rather than at the nadir. This view of intuition is supported by developmental studies of children's learning and of adults' acquisition of expertise, which have demonstrated a progression from detail-oriented and computational processes (e.g., trading off the magnitudes of risk and reward) to fuzzy and intuitive processing (people process less information more qualitatively as development progresses; Jacobs & Klaczynski, 2002; Reyna & Ellis, 1994). For example, my colleagues and I found that in deciding whether to admit a patient with chest pain to the hospital, expert cardiologists processed fewer dimensions of information than less expert physicians did and also processed those dimensions in a cruder all-or-none fashion (patients were either at risk or not at risk of an imminent heart attack; Reyna et al., 2003). Another difference between fuzzy-trace theory and other recent dual-process approaches is the role they give emotion in decisions that involve risk. Some dual-process theorists elevate emotion above reason, arguing that decision makers ought to rely on their gut feelings. As in other dual-process theories, emotion is important in fuzzy-trace theory: Gist representations capture the meaning of experience, including its emotional meaning. However, emotion is not viewed as an unerring signal of what is adaptive (Reyna et al., 2003).

Fuzzy-trace theory provides an alternative conception of rationality, compared with traditional theories of judgment and decision making. Any theory of rationality must provide a mechanism for achieving what is called the consistency criterion: Superficially different reasoning problems should be treated consistently. For example, if you choose surgery when it is described as having an 80% survival rate, you should still choose it if it is described as having a 20% mortality rate. In fuzzy-trace theory, the mechanism for achieving consistency is found in the sharing of gist. To the rational decision maker who is contemplating surgery, the gist of the risk of surgery is the same whether it is described in terms of survival or mortality rates. Fuzzy processing is also a source of irrational biases and inconsistencies, however. My colleagues and I (Reyna et al., 2003) have developed a taxonomy of these biases and inconsistencies in which degrees of rationality are specified. That is, errors in reasoning, judgment, and decision making are categorized as more or less advanced according to the type of processing that produced them. Some kinds of errors are seen as more irrational—more serious failings—than others.

In sum, ideas about working memory capacity that were traditionally invoked in judgment-and-decision-making research have been challenged by findings that reasoning and remembering are independent. Researchers such as Simon simply assumed that working memory capacity was an important factor, but research that has actually examined the relation between memory and reasoning does not support this assumption. Fuzzy-trace theory emphasizes alternatives to capacity explanations, independence of reasoning performance from memory constraints, and dual-process assumptions about memory and reasoning. Intuition has a special place in fuzzy-trace theory, and is considered an advanced form of reasoning because of developmental evidence about the typical sequence of errors as reasoners gain expertise in reasoning. Intuitions in reasoning come about as a result of parallel processing of multiple representations, uncertain retrieval of reasoning principles, and an overarching preference for gist representations (as opposed to verbatim representations). What do these assumptions predict about risk perception and decision making?

FUZZY PERCEPTIONS OF RISK

The period from the 1970s to the present produced a number of key findings about how people perceive risk and make decisions that involve risk. For example, researchers found that people often overestimate small risks (e.g., risks of complications from vaccinations) and that they choose options that involve taking a risk when potential outcomes are described as losses (e.g., a 2/3 chance that 600 people will die) but avoid taking a risk when the same outcomes are described as gains (e.g., a 1/3 chance that 600 people will be saved; Gilovich et al., 2002). Table 1 provides examples of both overestimation of small risks and shifts in risk taking associated with framing the same options as gains versus losses.

These classic findings used to be interpreted from a psychophysical viewpoint (e.g., perceptions of quantities such as probabilities were treated like perceptions of quantities of light or loudness), but are now accounted for with dual-process explanations, such as those discussed earlier. Dual-process explanations have also led to new, counterintuitive predictions (e.g., see Lloyd & Reyna, 2001; Reyna & Adam, 2003; Reyna & Hamilton, 2001). For both old and new findings, three questions (about representation, retrieval, and processing) form the basis of dual-process explanations in fuzzy-trace theory. Specifically, researchers explain particular judgments or decisions that involve risk by asking: (a) How are classes of events that are involved in reasoning about risk represented in memory? (b) What reasoning principles are cued in the particular context of reasoning? (c) Is reasoning subject to processing interference, especially from thinking about overlapping classes of events (e.g., the intersection of the two classes of people with genetic mutations and people with breast cancer)? Answers to these questions have been derived from research on judgments of probability and relative frequency, which are closely related to judgments of risk.

Representations of Risk

Consider the first question, about how classes of events involving risk are represented in memory. Suppose that a patient must decide whether to have surgery to prevent a 22% risk of stroke, and the surgeon informs the patient that the risk of dying from the surgery is 2%. What will the patient remember about the risks that are relevant to making this decision? According to fuzzy-trace theory, patients encode both verbatim and gist representations into memory, but verbatim memories become rapidly inaccessible. Data about patients' memory for surgical risks confirmed this prediction: Many patients misremembered the verbatim numbers indicating the risks of specific treatment options (Reyna & Hamilton, 2001). As discussed, however, decisions are usually based on gist representations of information, rather than verbatim representations. Although the data showed that patients misremembered the verbatim numbers, they were able to order the relevant classes of risks correctly: The risk of going without surgery was generally remembered as higher than the risk of surgery.

Patients understood the gist of the relative risks, their relative magnitudes, but did they understand the information essential for informed consent? According to fuzzy-trace theory, some errors are worse than others. Patients who err by declaring that surgery with 2% risk has no risk have not extracted the proper gist for informed consent, which requires recognition that the procedure involves some risk. Patients who err by recalling the risk to be 5% are further off the mark quantitatively, but they have a better grasp of the correct gist that the procedure involves taking a risk. Thus, understanding the gist that the surgery involves taking a risk is essential for informed consent. More generally, the literature is replete with examples of how a person's representation of gist (which reflects the person's education, emotion, culture, and worldview), rather than verbatim information, governs the perception of risk.

Table 1 summarizes additional examples of how fuzzy-trace theory's assumptions about gist predict results related to risk perception. For example, the table shows that very low risks described in relative terms, such as "half the risk," are perceived differently than the same objective risks described in absolute terms, such as "a .0000030 chance of injury for improved tires and a .0000060 risk for standard tires" (see Stone, Yates, & Parker, 1994).

Two examples from Table 1 illustrate how people base their estimates of risks on the gist of a class of events, objects, or people. In studies involving hypothetical and real patients, physicians tended to equate patients' probability of either coronary disease or heart attack with the overall probability of coronary disease, systematically ignoring the probability that patients could be at risk of a heart attack without having a significant probability of coronary disease (despite knowledge that such patients exist; Reyna et al., 2003). Physicians apparently estimated each risk by thinking of the gist of that class of patients: The typical coronary disease patient is not at risk of an imminent heart attack, but the typical patient at risk of a heart attack has coronary disease. Adding these two classes of risks together to determine overall risk, physicians ignored the atypical patients who are at risk of a heart attack but do not have significant coronary disease. Similarly, physicians and other health care professionals overestimated risk reduction provided by condoms because the gist of sexually transmitted infections is that they are fluid-borne infections (Reyna & Adam, 2003). Condoms seem to provide more protection than they actually do because they provide a barrier that reduces the sharing of fluids. However, condoms do not provide as much protection against skin-to-skin transmission; they do not provide as much reduction in risk as one might think based on a gist that diseases are transmitted by sharing fluids. Again, the nongist class of risks—infections transmitted in psychologically atypical ways, such as by skin-to-skin contact—was systematically ignored.

Retrieval of Reasoning Principles

With respect to the second question, concerning retrieval of reasoning principles, it is important to note that people often know and endorse the correct reasoning principle even though their reasoning on a specific problem is not based on it. For example, for people given a bag containing 10 blue plastic tokens and 5 red plastic tokens, it is a simple matter to judge the risk of accepting a wager on blue versus red. However, if asked which is more probable, blue tokens or plastic tokens, adults take a long time to answer, and children as old as 10 get the answer wrong. Children insist that there are more blue tokens than plastic ones, and make the same mistake even with problems having familiar content (e.g., given pictures of 7 cows and 3 horses, which total 10 animals, they insist that there are more cows than animals). Contrary to speculation, children do not get the token question wrong because of its unfamiliar content (tokens as opposed to farm animals) or because of linguistic ambiguity. Errors persist even when linguistic ambiguity is eliminated (i.e., the plastic tokens are described as "red or blue" to avoid the possible misinterpretation that the phrase "plastic tokens" refers to the smaller class of red tokens). Children fail to retrieve the principle that more inclusive classes (e.g., plastic tokens) are also more numerous or probable than the subclasses (blue plastic tokens) included in them, although they endorse that principle in other contexts (Reyna, 1991).

TABLE 1
Explaining Biases in Risk Perception and Decision Making

Type of bias	Task	Objective risk	Subjective risk	Gist representation	Explanation of bias
Overestimation of small risks (Gilovich, Griffin, & Kahneman, 2002)	Estimate risk of smallpox vaccination (1978)	8 deaths per 2.05×10^8 U.S. residents	23 deaths per 2.05×10^8 U.S. residents	Smallpox vaccine is risky	Denominator neglect
Overestimation of small risks ("3rd Smallpox Vaccine Death Reported," 2003)	Estimate risk of smallpox vaccination (2003)	17 people with heart problems per about 25,000 vaccinated	Risk considered large enough for IOM and two states to recommend suspension	"Despite the low numbers" (IOM), smallpox vaccine is risky	Denominator neglect
Framing risks (Reyna & Brainerd, 1991)	Choose between options to combat disease expected to kill 600 people	*Gain frame*: A: 200 people saved. B: 1/3 probability 600 saved; 2/3 probability no people saved. *Loss frame*: C: 400 people die. D: 1/3 probability no one dies; 2/3 probability 600 people die.	*Gain frame:* The risky option is frightening *Loss frame:* The risky option offers hope	*Gain frame*: Saving some people is better than saving none, so choose sure option *Loss frame*: Nobody dying is better than some dying, so choose risky option	Qualitative representation of options; retrieval of principles, such as saving some people is better than saving none
Base-rate neglect (Reyna & Brainerd, 1995)	Estimate risks of playground accidents	20 accidents playing on slides and 5 on swings; more children play on slides	20 accidents are riskier than 5 accidents	Slides are dangerous	Denominator neglect
Biases in integrating risks (Reyna, Lloyd, & Brainerd, 2003)	Estimate probability of CAD or risk of MI to decide hospital admission	Probability of being CAD patient or being MI patient = CAD&MI + CAD&notMI + notCAD&MI	Physicians estimated: probability of CAD or MI equals the probability of CAD	Probability typical CAD patient (not at risk of MI) plus probability typical MI patient (also has CAD) = probability of CAD (i.e., CAD&notMI + CAD&MI = CAD)	Neglects nongist class of patients at MI risk without CAD
Relative vs. absolute risk (Stone, Yates, & Parker, 1994)	Choose between products and estimate how much willing to pay for safer products	*Absolute risk format:* Example: Injury risk is .0000030 for an improved product and .0000060 for the standard product *Relative risk format:* Example: Injury risk for improved product is half that for standard product	For very small risks (tire blowouts, airplane accidents), people paid more for risk reduction with the relative than absolute risk format; for larger low risks, there was no difference between formats	Very small risks are edited to "essentially nil risk" (so both risks are seen as negligible in the absolute format and subjects are not willing to pay more for one than the other)	Qualitative representation of options; retrieval of principles, such as more safe is better than less safe

TABLE 1
Continued

Type of bias	Task	Objective risk	Subjective risk	Gist representation	Explanation of bias
Overestimation of reduction in risk (Reyna & Adam, 2003)	Estimate risk reduction for STIs provided by using condoms, based on FDA labeling	Risk reduction provided by condoms limited because some STIs transmitted skin-to-skin	Adolescents, physicians, and other health care professionals overestimated the extent of risk reduction for STIs provided by condoms	Gist of STIs for older people (syphilis, gonorrhea) and younger people (HIV) is fluid-borne infection, reduced with mechanical barriers (e.g., condoms)	Despite knowledge, professionals neglect nongist but highly prevalent classes of infections transmitted skin-to-skin (HPV, HSV)

Note. **IOM = Institute of Medicine; CAD = coronary artery disease, which leads to heart attacks; MI = myocardial infarction or heart attack; STIs = sexually transmitted infections; FDA = Food and Drug Administration; HIV = human immunodeficiency virus; HPV = human papillomavirus; HSV = herpes simplex virus.**

The developmental psychologist Jean Piaget originally introduced the class-inclusion task to study cognitive illusions in children (although, as predicted by fuzzy-trace theory, adults also find the class-inclusion question difficult because the classes are overlapping, a situation discussed in the next section). In an analogue of this class-inclusion task, adults typically rank the chances of a stereotypical liberal activist being a "feminist bank teller" as greater than her being a "bank teller" (again, even when possible ambiguity is eliminated—"a bank teller whether or not she is a feminist"), despite endorsing the inclusion principle that no one could be more likely to be a feminist bank teller than a bank teller. (Naturally, the *gist* of a class could be more or less extensive than its technically more inclusive class because gist captures the meaning or intension of a class rather than its extension; Reyna et al., 2003.) The gist of the class of feminist bank tellers fits the liberal activist better than the gist of the class of bank tellers (conservative types), contrary to the inclusion principle. In another article (Reyna, 1991), I have described how retrieval cues in the questions posed to reasoners determine whether they retrieve the correct reasoning principle.

Interference Effects in Processing

The third question concerns how errors in reasoning about risk arise as a result of processing interference. According to fuzzy-trace theory, overlapping classes cause processing interference. Reasoners focus on target members of a class and lose track of the larger universe of possibilities. That is, judgments of risk involve a target class of events (e.g., the winning tokens, the patients who survived) and a larger, more inclusive class of events that includes both targets and nontargets (e.g., the losing tokens, the patients who did not survive). People compare target and nontarget events (e.g., Are there more winning tokens or losing tokens?) and automatically extract the gist of which class of events is "bigger." However, they pay less attention to the more inclusive class, which is the denominator in the calculation of risk: Seventeen heart complications from smallpox vaccinations are more salient than the total number of vaccinations administered (Table 1). (Note the similarity to the earlier example in which the class of feminist bank tellers is more salient in the context of judging a liberal activist than is the total class of bank tellers, whether or not they are feminists.)

Denominator neglect occurs regardless of whether risk is expressed with probabilities or frequencies, and instead results from interference caused by overlapping classes (Reyna, 1991; Wolfe, 1995). Denominator neglect accounts for overestimation of low-probability risks (it is the denominator that makes them low), conversion errors in which the conditional probability of A given B is confused with the probability of B given A (the numerators of conditional probabilities are identical; only the denominators differ[1]), and the neglect of base rates (the overall frequency of events, the denominators, are neglected in favor of salient numerators; see Table 1).

The confusion of conditional probabilities is readily illustrated in widespread misunderstanding of genetic risks, such as the probability of a woman developing breast cancer if she has BRCA1 or BRCA2 mutations versus the probability of a woman with breast cancer having BRCA1 or BRCA2 mutations (Reyna, Lloyd, & Whalen, 2001). Patients confuse the two probabilities and think the latter probability is high, even after genetic counseling. Base-rate neglect occurs when people focus on the number of times a target event has happened without thinking about the overall number of opportunities for it to happen; 20 accidents on slides might be significant or not depending on the number of times children played on the slides. In fuzzy-trace theory, none of these processing errors reflects a lack of logic or conceptual competence, nor do the errors reflect working memory limitations. Rather, they are low-level bookkeeping errors that are made even late in development among advanced reasoners and are easily remedied by keeping classes of events distinct (see Reyna, 1991, for effective interventions with children and Lloyd & Reyna, 2001, for similar interventions with physicians).

Figure 1 illustrates the tenacity of denominator neglect even among individuals with expertise relevant to the problem they are considering. The following identical problem was presented to 82 physicians, 34 other health care professionals, 93 health educators (who counsel high school students about risks), and 258 high school students:

[1]The probability of A given B is calculated as the probability of both A and B occurring, divided by the probability of B; the probability of B given A is calculated as the probability of both A and B occurring, divided by the probability of A.

> Suppose the pre-test probability of disease is 10% and a diagnostic test has 80% sensitivity (80% of people with disease test positive) and 80% specificity (80% of people without the disease test negative). The test result is positive. What is the probability of disease, 30% or 70%?

Ignoring the denominator (and thus confusing the conditional probability of a positive result given disease with the conditional probability of disease given a positive result) yields an answer of 80%, which might be adjusted downward to 70% because of the low pretest probability. However, the correct answer is closer to 30% (given that 90% of people do not have the disease, false positives outnumber true positives). As Figure 1 shows, most people did not select the correct answer. The disparity between actual and perceived risk was large for people of all ages and levels of expertise. Those theorists who argue that errors in these problems are actually smart ignore the pervasive problem of false positives and negatives in medicine and other important real-life contexts (e.g., screening federal mail for biological agents). It is important in the real world to discriminate good from bad reasoning about risk.

Although processing interference remains a problem throughout life for most reasoners, representation of information in memory and retrieval of reasoning principles undergo changes as knowledge and experience are accumulated. As children grow to adulthood, they change from quantitative reasoners, who trade off amounts of risk and reward, to qualitative reasoners, who process categorical (e.g., some money is better than no money, no risk is better than some risk) gist (Reyna et al., 2003). For example, given a choice between a sure win of 5 prizes and a 50% chance of winning 10 prizes or winning nothing, adults prefer a sure win, whereas young children prefer the risky option that offers the possibility of more prizes. Young children reason quantitatively about the numerical difference between 10 prizes and 5 prizes, and they weigh this difference in outcomes (which favors the gamble) against the difference in the probability of winning between the sure option and the gamble (Reyna & Ellis, 1994). Adults reason qualitatively that winning some prizes is better than maybe winning none: The quantity of prizes is not the determinative factor.

Similarly, given a choice between hanging out at the mall or going to an unsupervised party, many adolescents prefer the risky option that offers the possibility of more fun. Although they are more risk averse than young children, adolescents analyze the decision by weighing risks and benefits like young children do; the mall-versus-party decision depends on the *amount* of fun and the *degree* of risk. Most parents would view these options in starker terms: No amount of fun can compensate for the risks, contrary to a strict cost-benefit analysis. For adults (but not necessarily for children and adolescents), the number of bullets in the chamber is irrelevant to the decision of whether to play Russian roulette. Adolescents deciding whether to go to the party mentally represent the problem as involving whether they would prefer to go to the mall and have a specific amount of fun or take a calculated, objectively small risk and have much more fun at the party. Using the reasoning principle that more fun is better than less fun, and applying it to the mental representation just described, which incorporates both risks and rewards, they decide that going to the party is preferred. In contrast, parents represent the decision as being between (a) having fun at the mall and (b) taking a risk and either having fun at the party or losing everything. They apply the reasoning principle that one should avoid risk and avoid catastrophic outcomes.

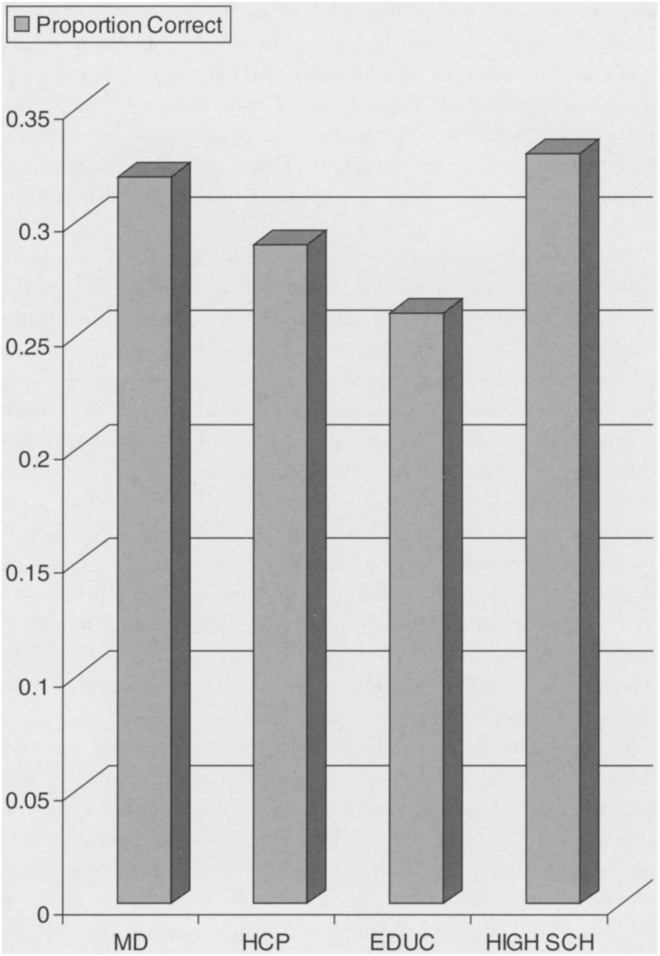

Fig. 1. **Illustration of denominator neglect that occurs despite expertise. Participants were asked to indicate whether 30% or 70% was a better estimate of the risk of low-prevalence disease when a patient tested positive using a less-than-perfect test (80% sensitivity and 80% specificity). The respondents were physicians (MD), health care professionals (mainly nurses; HCP), health educators (EDUC), and high school students (HIGH SCH). From Reyna and Adam (2003) and additional unpublished data.**

According to fuzzy-trace theory, the crude all-or-none categorization that adults apply in this situation is more advanced than the subtle shadings that adolescents perceive. Global categorical policies (e.g., avoid risk) exist on a higher plane of rationality, cutting across details of amounts of risk and reward.

CONCLUSIONS

Perceptions of risk precipitate decisions to go to war, to vaccinate against smallpox, to reduce exposure to sexually transmitted diseases, to report suspicious illnesses to public heath authorities, or to admit to the hospital a patient who has chest pain and is at risk of a heart attack. Psychological science now offers predictive theories that explain dangerous biases in reasoning about risk and provide insights into how these biases can be corrected. In particular, research on memory provides a rich repertoire of empirically tested concepts that help explain the psychology of risk: the encoding of dual verbatim and gist representations of information and the reliance on the latter whenever possible; the dependence of reasoning on retrieval cues that elicit values and principles stored in long-term memory; and the vulnerability of reasoning about risk to processing interference from overlapping classes of events, resulting in denominator neglect.

These memory concepts are used in fuzzy-trace theory to explain how dual processes operate in reasoning and decision making. The basic idea is that intuitive gist-based reasoning increasingly supplants analytical verbatim-based reasoning as children gain experience and as novices become experts. As Figure 1 shows, this development does not mean that reasoning becomes immune to all sources of error. In contrast to some other dual-process theories, this theory posits that intuition is advanced, errors are bad, and emotions are not necessarily good. Within this theory, a detailed processing model distinguishes degrees of rationality based on observations of similar developmental progressions in types of errors across many tasks. The processing model also accounts for well-known findings about risk perception, such as overestimation of small risks because of denominator neglect, as well as new findings, such as crude all-or-none processing of risks among expert cardiologists (compared with more fine-grained processing by physicians with less expertise).

Gist-based reasoning requires neither exact nor inexact numbers (although decision makers prefer to extract their own gist as opposed to having it extracted for them). Such reasoning can proceed when "it is impossible to quantify the risk," to quote the director of the Centers for Disease Control and Prevention when she discussed the risk of terrorist attacks using smallpox. If gist-based reasoning is robust in the face of this kind of ambiguity, as research suggests, and if it develops with experience, it ought to be possible to marshal and hone it to produce better decision making when outcomes are uncertain. In order to identify the most efficient nurturing conditions for better gist-based thinking, however, researchers need theories that hold reasoners accountable for bad reasoning. A challenge in future research will be to acknowledge that intuition is adaptive and even advanced, but nevertheless imperfect in systematic ways.

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