Risk Analysis, Vol. 23, No. 2, 2003

Fuzzy-Trace Theory, Risk Communication, and Product Labeling in Sexually Transmitted Diseases

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Health care professionals are a major source of risk communications, but their estimation of risks may be compromised by systematic biases. We examined fuzzy-trace theory's predictions of professionals' biases in risk estimation for sexually transmitted infections (STIs) linked to: *knowledge deficits* (producing underestimation of STI risk, re-infection, and gender differences), *gist-based mental representation of risk categories* (producing overestimation of condom effectiveness for psychologically atypical but prevalent infections), *retrieval failure for risk knowledge* (producing greater risk underestimation when STIs are not specified), and *processing interference involving combining risk estimates* (producing biases in post-test estimation of infection, regardless of knowledge). One-hundred-seventy-four subjects (experts attending a national workshop, physicians, other health care professionals, and students) estimated the risk of teenagers contracting STIs, re-infection rates for males and females, and condom effectiveness in reducing infection risk. Retrieval was manipulated by asking estimation questions in two formats, a specific format that "unpacked" the STI category (infection types) and a global format that did not provide specific cues. Requesting estimates of infection risk after relevant knowledge was directly provided, isolating processing effects, assessed processing biases. As predicted, all groups of professionals underestimated the risk of STI transmission, re-infection, and gender differences, and overestimated the effectiveness of condoms, relative to published estimates. However, when questions provided better retrieval supports (specified format), estimation bias decreased. All groups of professionals also suffered from predicted processing biases. Although knowledge deficits contribute to estimation biases, the research showed that biases are also linked to fuzzy representations, retrieval failures, and processing errors. Hence, interventions that are designed to improve risk perception among professionals must incorporate more than knowledge dissemination. They should also provide support for information representation, effective retrieval, and accurate processing.

KEY WORDS: Fuzzy-trace theory; sexually transmitted infections; risk communication; risk estimation; health care professionals

1. INTRODUCTION

Public health messages are delivered through various routes. A frequently used route is to disseminate information to health care professionals, who, in turn, convey that information to patients. Although professionals are a vital link in risk communication, they can be a weak link when psychological processes interfere with their ability to understand risk. Fuzzy-trace theory pinpoints specific problems in understanding and processing risk estimates that afflict both professionals and the lay public (e.g., Reyna & Brainerd, 1994, 1995a; Reyna & Hamilton, 2001). In this article, we discuss these problems and illustrate them with data

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gathered from health care professionals concerning estimates of adolescents' risk of acquiring sexually transmitted diseases. The data have implications for knowledge dissemination, product labeling, and formatting of risk information for professionals and the public.

According to fuzzy-trace theory, errors in risk estimation spring from distinct sources, including knowledge deficits, failure to encode appropriate mental representations of risk categories, failure to retrieve known information in context, and processing interference arising from difficulties in processing nested or overlapping categories of risks. (See Reyna, Lloyd, and Brainerd, in press, for an extended discussion of these types of errors.) Before we discuss theoretical details, however, a few caveats are in order.

Although we set out to test specific hypotheses generated by fuzzy-trace theory (e.g., Reyna & Brainerd, 1995a; Reyna, Lloyd, & Brainerd, in press), we acknowledge that some hypotheses are broadly consistent with alternative theories, such as support theory, which predicts differences between packed and unpacked categories (e.g., Tversky & Koehler, 1994). In contrast to support theory, however, fuzzy-trace theory incorporates mechanisms of representation, retrieval, and processing that predict not only unpacking effects, but also other memory effects. Mathematical models of fuzzy-trace theory have been developed (e.g., Brainerd, Reyna, & Mojardin, 1999; Reyna & Brainerd, 1995a) that subsume and extend older distinctions, such as familiarity and recollection, and that differ from other dual-processing models (e.g., Epstein, 1994; Sloman, 1996). The goal of research on fuzzy-trace theory has been to encompass data from divergent perspectives, while generating new, counterintuitive data and predictions (e.g., Reyna, 2000; Reyna & Brainerd, 1992, 1998). Fuzzy-trace theory's "assumptions," therefore, are motivated by specific findings.

Thus, predictions we spell out for risk estimation of sexually transmitted diseases are consistent with results of other studies. In particular, we apply principles first articulated in studies of cognitive development in children (e.g., Reyna & Brainerd, 1994) to the growth of expertise in adults, namely, to changes in risk estimation as health care professionals gain domain-specific knowledge. Because the approach is theoretical, the sources of bias that we delineate for judgments about sexually transmitted diseases can be generalized to other judgments about risk (e.g., Lloyd, Reyna, & Whalen, 2001; Reyna & Hamilton, 2001; Reyna, Lloyd, & Whalen, 2001; Stone, Yates, & Parker, 1994).

1.1. Theoretical Background

Fuzzy-trace theory concerns memory, reasoning, and their development (Reyna & Brainerd, 1995a, 1998). A core assumption of the theory is that people encode *multiple representations* of information that vary in precision from detailed "verbatim" traces to vague "gist." For quantitative information about risk and probability, these representations are analogous to scales of measurement ranging from crude categorical or nominal distinctions to fine-grained ratio-level ones. The concept of "gist" builds on earlier research in psycholinguistics (e.g., Kintsch, 1974), but has been extended to pictorial, numerical, and other nonverbal information (Reyna & Brainerd, 1991a, 1995b). Reasoners exhibit a *fuzzy processing preference*: they tend to operate on the least precise level of representation that can be used to accomplish a judgment or decision-making task. Task calibration serves to move processing to greater precision if the task requires it. For instance, if the required response is to generate an exact risk estimate, as opposed to choose between options, finer quantitative distinctions among levels of risk are required (e.g., Reyna & Brainerd, 1995a).

To take one example, in choosing between an assured prize of $100,000 and a gamble with a one-third chance of winning $300,000 (and a two-thirds chance of winning nothing), most people prefer the sure gain. However, they apparently do not make this decision because of fine-grained differences in outcomes, probabilities, or overall expected values (e.g., Reyna & Brainerd, 1991b). The simple qualitative superiority of winning some money as opposed to nothing—the bottom-line gist of the decision—drives the choice of the sure option (e.g., the preferences for gain and loss versions of this problem are similar when all the numbers are replaced by vague verbal phrases such as "some amount"). The gist of a decision varies with age, education, culture, stereotypes, worldview, and other factors that affect the meaning or interpretation of information (e.g., Reyna, 1996a, 1996b; Reyna & Brainerd, 1998; Reyna & Kiernan, 1994, 1995; Slovic & Peters, 1998).

Once the gist of presented information has been mentally represented, reasoners must make contact with information stored in memory (such as values and preferences) in order to derive judgments and decisions. In the example above, decisionmakers apply the principle that "some money is better than none" in order to choose the sure option over the gamble. (Some theorists have claimed that preferences are constructed rather than stored in memory; according to fuzzy-trace theory, preferences, too, are represented as generic gists in long-term memory and instantiated in context (Reyna & Brainerd, 1991a, 1995a).) Similarly, in estimating the overall risk associated with a category such as sexually transmitted diseases, reasoners must retrieve information from memory about members of the category (e.g., the risk of HIV, syphilis, gonorrhea, and so on). Thus, in estimating an adolescent girl's risk of contracting a sexually transmitted disease from unprotected intercourse, professionals call on their knowledge of the prevalence of different sexually transmitted diseases, among other factors.

Naturally, if a health care professional has little or no knowledge about the prevalence of different sexually transmitted diseases, they are in a poor position to make accurate risk estimates. In addition, professionals with greater domain-specific knowledge, such as experts, are likely to formulate more accurate estimates than nonexperts. Thus, knowledge deficits are among the simplest sources of risk estimation errors. They are not a trivial source of error, however, because the published literature on sexually transmitted diseases is growing rapidly and is difficult to keep abreast of. For example, new research suggests that infection and re-infection rates for teenage girls are substantially higher than previously estimated (e.g., Jancin, 1999; Orr *et al.*, 1999, 2001). It is likely, therefore, that health care professionals will underestimate the risk of sexually transmitted disease in this population.[2]

Some of this increase in disease rates can be attributed to the rates of psychologically atypical but prevalent infections, such as human papillomavirus (HPV). For example, Peyton *et al.* (2001) reported a high HPV prevalence rate of 39.2% among women aged 18 to 40. We distinguish between straightforward knowledge deficits (the absence of information in memory) and the fuzzy representation of categories. According to fuzzy-trace theory, risk under- and overestimation also occur because risk categories are fluid and impressionistic, rather than Aristotelian lists of necessary and sufficient features (e.g., Reyna, 1996b; Reyna & Kiernan, 1995). The gist of a category in a given context may encompass more or less than the technical extension of the category.[3] The typical representation of the category of sexually transmitted disease, for example, is fluid-borne illness, such as HIV and gonorrhea, which implicitly highlights risk reduction methods that limit exchange of fluids. If the gist of sexually transmitted diseases is "fluid-borne," then skin-to-skin transmission, as in HPV (transmitted through epithelial contact) and herpes simplex virus (transmitted through both fluid and skin-to-skin contact), is a less salient mode of infection.

Despite the elasticity of gist across contexts, we do not claim that people are unaware of atypical category members or features, such as skin-to-skin transmission of disease, only that certain members and features are more salient than others (e.g., Reyna, 1991). Thus, fuzzy-trace theory predicts that not only will the risk of sexually transmitted diseases overall be underestimated because of a failure to fully consider psychologically atypical as well as typical diseases, but also that the effectiveness of condoms and other barrier methods in reducing risk will be overestimated. Overestimation of risk reduction is likely because the gist of the category, fluid-borne illness, makes methods that limit fluid exchange seem to address "the" mode of transmission. Interestingly, because this kind of error is one of failing to fully consider psychologically atypical diseases, it occurs despite knowledge of these diseases. Known information is simply not salient in the risk estimation process (see also Brainerd & Reyna, 1990).

In addition to problems in risk estimation caused by lack of knowledge and fixation on the gist of categories, rather than their full extension, cues in the environment operate selectively to elicit only some stored knowledge. Different descriptions of the same risk category are better retrieval cues for stored knowledge than other cues (e.g., Reyna, Lloyd, & Brainerd, in press; Tversky & Koehler, 1994). For

[2] Risk estimates based on the published literature are not necessarily assumed to rise to the level of "gold standards." We are interested in comparing estimates to the best scientific evidence available, acknowledging that professional estimates might justifiably differ from this evidence.

[3] The representativeness heuristic also assumes that typicality affects probability judgments (i.e., instances that are more typical of a category are also judged as more probable), which is not incompatible with the account offered here. However, a key aspect of representativeness is that specifying typical details concerning an instance increases perceived representativeness (despite objectively decreasing probability). The gist of a category, in contrast, is vague and impressionistic rather than detailed and specific. In addition, the representativeness heuristic is not an elaborated process model. The properties of gist representations have been well characterized in prior research (which produces additional predictions that go beyond the scope of this article; see Reyna, Lloyd, & Brainerd (in press); Reyna & Brainerd (1995a)), elaborated in process models, and parameters have been estimated and tested in experiments.

example, estimating the risk of death for a 20-year-old male usually elicits a low estimate because a young age suggests a low probability of death from disease. However, if asked to judge risk of death from violence, vehicular accidents, disease, and all other causes for the same 20-year-old, estimates increase because it is well known that young males have an increased risk of death from violence and accidents (e.g., Reyna, Lloyd, & Brainerd, in press). Unpacking the causes of death elicits knowledge about increased risks for young males.

Finally, in estimating the overall risk associated with a category such as sexually transmitted diseases, reasoners must not only retrieve risk information about members of the category (e.g., the risk of HIV, syphilis, gonorrhea), they must combine those risks coherently. For example, considering just two risks, if the risk of contracting HPV is high and the risk of HIV is low, then the risk of contracting *a* sexually transmitted infection is high because the overall judgment is disjunctive (i.e., A or B). According to fuzzy-trace theory, such judgments are vulnerable to error because they involve combining probabilities of overlapping classes or categories. Nested or overlapping classes produce processing interference, namely, confusion in keeping track of appropriate sets and subsets for judgments. Conversion errors (P A/B confused with P B/A) and denominator neglect for conditional probability judgments and other so-called inclusion illusions are effects of such processing interference (e.g., Reyna, 1991; Reyna & Brainerd, 1993; Wolfe, 1995). Other judgments that involve combining probabilities, such as conjoining probabilities or updating base rates (prevalence rates) with additional diagnostic information (e.g., a test result), are also subject to similar processing interference (Reyna, Lloyd, & Brainerd, in press; Reyna, Lloyd, & Whalen, 2001).

In summary, fuzzy-trace theory predicts systematic distortions in risk estimation that can be linked to knowledge deficits, gist-based mental representation of risk categories, retrieval failure for risk knowledge, and processing interference involving combining risk estimates. Although our focus in this article is on health care professionals, these processes also describe patients' estimates of risk, although knowledge-based errors are likely to be larger (e.g., Reyna *et al.*, in press).

1.2. Specific Predictions

Our conception of rational judgment is the degree to which reasoning includes accurate knowledge, appropriate mental representation of knowledge, retrieval of relevant knowledge in context, and implementation of that knowledge coherently in judgment tasks, such as risk estimation. Thus, ideal reasoning should satisfy both internal coherence and external correspondence with reality. Although knowledge, representation, retrieval, and processing coherence are required for ideal reasoning, their validity is determined by their relevance in a context. In contrast to some evolutionary approaches to rationality, relevance is determined by the requirements of the task itself, *a priori*, not by what people do, *a posteriori* (see Reyna, 2000; Reyna & Brainerd, 1994, 1995a; Reyna, Lloyd, & Brainerd, in press, for further discussions of rationality). Building on prior work on rationality, fuzzy-trace theory distinguishes different types of reasoning errors based on detailed process analyses (Reyna & Brainerd, 1994, 1995a). We predicted that health care professionals would be subject to these predictable sources of error in estimating risks associated with sexually transmitted infections (STIs).

1.2.1. Knowledge Deficits and Representational Biases

We predicted that simple risk estimation errors would be associated with knowledge deficits concerning new research that infection and re-infection rates for teenage girls are substantially higher than previously estimated. These deficits are likely to be observed across a spectrum of training simply because the information is not yet widely available. Other knowledge deficits, such as lack of information about greater biological susceptibility to infection among girls, would be associated with differences in level of training because such information is currently available and typically covered in advanced training.

Fuzzy-trace theory also predicts misunderstanding of specific Centers for Disease Control and Prevention (CDC) and Food and Drug Administration (FDA) statements about condoms' effectiveness in reducing sexually transmitted infections and their sequelae. These statements, which are quoted below, describe risk reduction for gonorrhea, herpes simplex virus (HSV) infection, genital ulcers, genital warts, syphilis, pelvic inflammatory disease, HIV infection (and AIDS), hepatitis B virus, and chlamydia. According to theory, mental representations of risk are qualitative (gist-based) rather than quantitative, even among health professionals. Professionals' risk estimates are likely to be imprecise and based on the gist of categories, producing risk underestimation associated with atypical category members (e.g., human papillomavirus, HPV). Although CDC and FDA statements concerning risk reduction apply primarily to fluid-borne illness, the magnitude of risk reduction benefits are predicted to generalize (inappropriately) to skin-to-skin transmission, as in HPV and herpes simplex virus. Hence, professionals are predicted to underestimate STI risk (especially of HPV), re-infection, and gender differences, and to overestimate condoms' effectiveness for psychologically atypical but prevalent diseases (such as HPV and herpes simplex virus).

1.2.2. Failure to Retrieve Relevant Knowledge

Reasoning errors often occur despite excellent memory for relevant facts. Experiments that have teased apart sources of errors have shown that reasoners acted on the wrong representation for problems they were capable of solving, or they failed to retrieve their knowledge, or they failed to implement knowledge that was retrieved (e.g., Brainerd & Reyna, 1990; Reyna, 1996a; Reyna & Brainerd, 1991b, 1995a, 1998; Reyna & Ellis, 1994). These results support the intuitionist view of fuzzy-trace theory that reasoning is a dynamic, parallel, and uncertain process in which multiple representations of the same information are stored, stored knowledge is cued with some probability, and the execution of processing is sometimes unreliable (e.g., Reyna & Brainerd, 1991a). Retrieval failure—not noticing in a specific context that known facts are relevant—is a failure of insight, but is a less profound mistake than an absence of knowledge. Retrieval failures can sometimes be remedied easily, for example, by prefacing a subtle task with one in which the relevance of the facts is more obvious. In this study, we use just such a simple remedy by "unpacking" the category of STIs by listing specific exemplar diseases, and asking respondents to re-estimate the overall STI risk. Providing these specific retrieval cues should increase risk estimates for the category of STIs.

1.2.3. Processing Interference

Once retrieved, relevant knowledge must be applied coherently to the facts of the problem. Reasoners may have the requisite knowledge and even be aware of its relevance, but still get bogged down in the mechanics of processing. Syllogistic reasoning, and other tasks involving overlapping classes, provides a common example of such processing interference (Johnson-Laird, 1983; Reyna, 1991, 1995). Given premises of the form *All A are B* and *Some B are C*, reasoners can lose track of the "marginal" members of the classes (e.g., the Bs that are not A), and erroneously conclude that *Some A are C*. So-called Bayesian updating of probability judgments (taking prevalence rate into account in judging the probability of disease once diagnostic test results are known) similarly involves overlapping classes (e.g., the classes of patients with positive test results and those with the disease) and resulting processing interference (Wolfe, 1995). Using a notational system (e.g., Venn diagrams or distinctive labels) that allows reasoners to keep track of the classes being processed virtually eliminates this type of error (Agnoli, 1991; Reyna, 1991). We have argued that these processing errors do not reflect an absence of reasoning competence, but instead reflect sensitivity to interference in executing that competence. Processing interference is the least likely error to be overcome by advanced reasoners, and continues to be a source of performance decrements despite increases in knowledge and expertise. Therefore, we predict high levels of these kinds of risk estimation errors regardless of level of training.

1.2.4. Summary of Errors

In summary, the following risk errors can be ordered from least advanced to most advanced, respectively (cf. Table I).

1. *Competence*: Lack of knowledge (e.g., lack of a knowledge of high prevalence rate for HPV).
2. *Representation*: Failure to encode appropriate gist (e.g., encoding the gist of STIs as fluid-borne).
3. *Retrieval*: Failure to retrieve appropriate knowledge in context (e.g., underestimating risk of STIs because of failure to fully retrieve and consider rates for different infections).
4. *Processing*: Errors in implementing reasoning despite reasoning competence and accurate knowledge (e.g., overestimating the probability of a disease with a low prevalence rate, given a positive diagnostic test result).

2. METHOD

2.1. Subjects

The 174 respondents to the risk questionnaire included 82 physicians, 34 other health care

Table I. Fuzzy-Trace Theory's Explanations and Predictions for Risk Estimation Biases

Knowledge Deficits
- Knowledge deficits among simplest kinds of risk estimation errors: New research suggests infection and re-infection rates for teenage girls are higher than previously estimated. Target of traditional interventions.
- Predictions: Underestimation of STI risk (especially of HPV), re-infection, and gender differences.

Representational Biases
- Risk representations are qualitative (gist-based) rather than quantitative.
- Gist representations: Comprehension of information; encoded in parallel with facts, quantitative details (verbatim representations).
- Fuzzy-processing preference.
- Predictions: Overestimate condoms' effectiveness for psychologically atypical but prevalent diseases (such as HPV). Although CDC and FDA statements apply primarily to fluid-borne illness, risk estimates generalize (inappropriately) to skin-to-skin transmission, as in HPV.

Failure to Retrieve Relevant Knowledge
- Judgment errors occur despite knowledge. Retrieval failure—not noticing in a specific context that known facts are relevant—is a failure of insight, but less profound mistake than lack of knowledge.
- Retrieval failures can often be remedied easily: "unpacking" the category of STIs by listing specific exemplars, and asking respondents to re-estimate the overall STI risk.
- Prediction: Providing these specific retrieval cues should increase risk estimates for category of STIs.

Processing Interference
- Once retrieved, relevant knowledge must be applied coherently to facts.
- Processing interference: Getting bogged down in the mechanics of processing.
- Inclusion illusions: "Bayesian updating" of probability judgments (taking prevalence rate into account in judging the probability of disease once diagnostic test results are known) involves overlapping classes (e.g., the classes of patients with positive test results and those with the disease).
- Processing interference is least likely error to be overcome by experts; continues to be a source of error despite increases in knowledge.
- Prediction: More and less knowledgeable subjects will exhibit similar processing interference errors.

professionals (e.g., nurses), and 34 medical students and graduate students in public health. (Another eight Ph.D. faculty responded, but their data are not reported due to small sample size.) An additional sample of 24 health care professionals attending a national Workshop on Scientific Evidence for Condom Effectiveness and STD Prevention (sponsored by the NIH, CDC, and others) answered the same questions, with the exception of the question concerning birth control (see *Questionnaire* below). The demographics of the total sample were as follows: 48% female, 52% male; 79% white non-Hispanic, 7% white Hispanic, 6% Asian, 2% African American, and 6% other or omitted. Ethnicity was similar across groups except for the workshop sample, which was 88% white non-Hispanic, 4% African-American Hispanic, and 8% other or omitted. Gender representation differed across groups. In the workshop group, the percentages were 25% female and 75% male. In the physicians group, the percentages were 38% female and 62% male. In the other health care professionals group, the percentages were 85% female and 15% male. In the student group, the percentages were 53% female and 47% male.

Responses of this sample for one question were compared to those for three samples of undergraduates taking freshman- and sophomore-level courses: 107 students in psychology, 84 in chemistry, and 46 in Mexican-American studies. These students answered the target question as part of a longer questionnaire containing a variety of critical thinking questions.

2.2. Procedure

Written questionnaires were distributed to health care professionals attending grand rounds in internal medicine, emergency medicine, adolescent pediatrics, and public health at multiple sites, including teaching, community, county, and veterans' hospitals. This sample of professionals attending grand rounds is seeking, and is more likely to be exposed to, up-to-date research information. Subjects were instructed that participation would involve answering an anonymous survey, which took approximately 20 minutes. Subjects were told that the questionnaire concerned health care professionals' perceptions of risks regarding pregnancy and sexually transmitted infections, and that their participation was strictly voluntary. After written informed consent was secured, subjects received general instructions concerning the questionnaire. For questions soliciting a numerical risk estimate, subjects were given the following instructions.

INSTRUCTIONS: Use the following scale, which ranges from 0% risk (no risk at all) to 100% (completely certain) by placing a mark on the number line (as shown below).

0 . . 10 . . 20 . . 30 . . 40 . . 50 . . / . . 60 . . 70 . . 80 . . 90 . . 100%

To avoid ambiguity, subjects were explicitly instructed to include human papillomavirus among "sexually transmitted infections."

2.3. Questionnaire

All subjects, except for those attending the Workshop on Scientific Evidence for Condom Effectiveness and STD Prevention, responded to 13 questions concerning risk of pregnancy, pregnancy prevention, risk of acquiring sexually transmitted infections, and effectiveness of condoms. (See Appendix for the questions in their entirety.) For the group attending the workshop, the question about pregnancy prevention was divided into two questions (for a total of 14 questions). Their questionnaire elicited separate judgments for "theoretical effectiveness" and for "use effectiveness (typical use)" for methods of birth control.

The first few questions concerned widely circulated risks and probabilities associated with pregnancy. Specifically, the first question asked subjects to estimate the risk of pregnancy for teenagers having unprotected intercourse for one year using the 0–100% scale shown above. The second question asked subjects to rank the effectiveness of different methods of birth control, including abstinence (defined as "no sexual activity"), birth control pills, condoms, Depo-provera (injected), diaphragm, and withdrawal. Subjects were then asked to rank a teenager's risk of contracting the following sexually transmitted infections: chlamydia, gonorrhea, HIV or AIDS, human papillomavirus, and syphilis.

The next several questions concerned more subtle risks associated with sexually transmitted infection, including gender differences in biological susceptibility and risks associated with direct versus indirect exposure to multiple partners. Although such information is available and covered in advanced professional training, subjects lacking specialized domain knowledge would not necessarily be expected to respond in conformity to the literature.

At the next level of subtlety, to determine the extent of deviation from estimates obtained in recent research, subjects were asked to estimate (1) how much a young woman's risk of contracting a sexually transmitted infection jumps with each new sexual partner, (2) risk of re-infection for an urban teenage girl seven months after treatment, and (3) risk of re-infection for her male partner after seven months. These questions were designed to determine whether professionals would provide risk estimates that differed appreciably from new research indicating that infection and re-infection rates for teenage girls are substantially higher than previously estimated. Although some questions concerned males and others females, we focus on responses to questions concerning females because of the greater availability of accurate published data about risk estimates.

Subjects were asked again how much a young woman's risk of contracting a sexually transmitted infection jumps with each new sexual partner, but specific infections were now enumerated. Retrieval was manipulated by asking estimation questions in two formats, a specific format that "unpacked" the STI category (infection types) and a global format that did not provide specific cues. The question concerning estimating the overall risk of contracting STIs and the later question concerning the same estimate—but with STIs specified—were separated by two other questions. (For both the global and specified questions, the phrase "including HPV" was added to avoid ambiguity.) None of the respondents reported noticing that these referred to the same risk estimate in different forms.

The statements on condom effectiveness, which respondents were asked to interpret in terms of estimates of risk reduction, were direct quotes from Centers for Disease Control and Prevention documents (e.g., Division of STD Prevention, 1999) and FDA labeling appearing on condom packages. The CDC statement is: "Condom use reduces the risk for gonorrhea, herpes simplex virus (HSV) infection, genital ulcers, and pelvic inflammatory disease. In addition, intact latex condoms provide a continuous mechanical barrier to HIV, HSV, hepatitis B virus, *Chlamydia trachomatis*, and *Neisseria gonorrhoea.*" The FDA statement is: "If used properly, latex condoms will help to reduce the risk of transmission of HIV infection (AIDS) and many other sexually transmitted diseases, including chlamydia, genital herpes, genital warts, gonorrhea, hepatitis B, and syphilis."

The last question provided information about prevalence rate, sensitivity, specificity, and diagnostic test result, and asked respondents to select which of two probabilities best described the post-test probability of infection. This question assessed processing deficits independently of knowledge deficits or the gist of risk categories because the disease was not specified. Because all relevant information is provided (prevalence rate, sensitivity and specificity of diagnostic tests, test results), knowledge of sexually transmitted infections is not necessary for a correct response.

In summary, the questionnaire was designed to investigate health care professionals' biases in risk estimation for sexually transmitted infections, separating biases caused by knowledge deficits from those caused by incomplete representations, retrieval failures, and processing errors. Knowledge deficits were predicted to produce underestimation of infection and re-infection risk for young women, and representational biases should produce underestimation of transmission risk for human papillomavirus (HPV) and overestimation of condom effectiveness. Further, we expected retrieval deficits to produce greater risk underestimation when STIs were not specified. Finally, we expected processing deficits to produce biases in post-test estimation of infection, regardless of knowledge.

3. RESULTS AND DISCUSSION

Tables II–V display mean responses, standard deviations (where appropriate), and percentages for responses to questionnaire items for the four groups of health care professionals or trainees: professionals attending a workshop on Scientific Evidence for Condom Effectiveness and STD Prevention, as well as physicians, other health care professionals (primarily nurses), and students attending grand rounds, respectively. (The remaining data are displayed in figures.) Preliminary analyses distinguishing grand round type (internal medicine, emergency medicine, adolescent pediatrics, or public health) and type of student (medical students vs. graduate students in public health) found no reliable differences among these groups. Thus, subsequent analyses collapsed across these factors. Some analyses compared the four groups to one another (a norm-referenced approach), whereas other analyses compared each groups' estimates to published estimates using goodness-of-fit *t*-tests (a criterion-referenced approach). Because several one-way analyses of variance were conducted to compare groups (albeit for different items), Type I error is a possibility. Due to the fact that the tests were generally nonsignificant, Type I error does not seem to be a problem.

The initial question concerning risk of pregnancy for a teenager having unprotected intercourse over one year had been thought to be routine knowledge among health care professionals. Surprisingly, each of the groups provided risk estimates that were significantly lower than reported figures, which have recently ranged from 85% (Trussell *et al.*, 1995) to 89% (Trussell & Vaughn, 1999). Professionals' estimates of pregnancy risk ranged from 73–77% (and did not differ significantly from one another based on a univariate analysis of variance comparing the four groups' estimates). (For each of the four groups, the target values fell within the broad 95% confidence intervals.) A one-sample *t*-test was performed for each group separately comparing the sample estimate to the lower reported rate of 85%; each group was found to differ significantly from that value: for the workshop group, $t(22) = -3.31$, $p < 0.004$; for the physicians, $t(80) = -7.13$, $p < 0.001$; for the other health care professionals, $t(33) = -2.93$, $p < 0.007$; and for the students, $t(31) = -2.67$, $p < 0.02$. It should be noted for this question, and for others, that significant differences from published estimates do not necessarily mean that

Table II. Questionnaire Responses for Members of the Workshop on the Scientific Evidence for Condom Effectiveness and STD Prevention

Question	Mean	*SD*	Response Type
1. One-year pregnancy risk for teenager	73%	18%	Risk %
2. Theoretical effectiveness of birth control			
Abstinence	1.29	1.04	Rank
Depo-provera	2.42	0.78	Rank
Birth control pills	2.62	0.58	Rank
Condoms	3.83	0.76	Rank
Diaphragm	5.00	0.51	Rank
Withdrawal	5.83	0.38	Rank
3. Use effectiveness of birth control			
Depo-provera	2.00	1.02	Rank
Birth control pills	2.42	0.78	Rank
Abstinence	2.57	1.93	Rank
Condoms	3.79	1.02	Rank
Diaphragm	4.50	0.72	Rank
Withdrawal	5.58	1.06	Rank
4. Infection risk for sexually active teenager			
HPV	1.74	1.10	Rank
Chlamydia	1.83	0.58	Rank
Gonorrhea	2.52	0.73	Rank
Syphilis	4.26	0.62	Rank
HIV or AIDS	4.61	0.58	Rank
5. Who is at greater risk of STI?			
Suzy had 12 partners	48%	N/A	Choice %
Juanita's boyfriend had 12 partners	4%	N/A	Choice %
Same risk for Suzy and Juanita	48%	N/A	Choice %
6. Juanita is at no risk because boyfriend is monogamous			
True	4%	N/A	Choice %
False	96%	N/A	Choice %

Table III. Questionnaire Responses for Physicians Attending Grand Rounds in Internal Medicine, Emergency Medicine, Adolescent Pediatrics, and Public Health

Question	Mean	*SD*	Response Type
1. One-year pregnancy risk for teenager	70%	19%	Risk %
2. Theoretical effectiveness of birth control			
Abstinence	1.28	1.12	Rank
Depo-provera	2.40	0.87	Rank
Birth control pills	2.63	0.62	Rank
Condoms	3.83*	1.00	Rank
Diaphragm	4.10*	0.98	Rank
Withdrawal	5.55*	1.06	Rank
3. Infection risk for sexually active teenager			
HPV	1.67	1.01	Rank
Chlamydia	1.84	0.68	Rank
Gonorrhea	2.66	0.69	Rank
Syphilis	4.32	0.69	Rank
HIV or AIDS	4.49	0.72	Rank
4. Who is at greater risk of STI?			
Suzy had 12 partners	37%	N/A	Choice %
Juanita's boyfriend had 12 partners	1%	N/A	Choice %
Same risk for Suzy and Juanita	61%	N/A	Choice %
5. Juanita is at no risk because boyfriend is monogamous			
True	1%	N/A	Choice %
False	99%	N/A	Choice %

Table IV. Questionnaire Responses for Health Care Professionals Attending Grand Rounds in Internal Medicine, Emergency Medicine, Adolescent Pediatrics, and Public Health

Question	Mean	*SD*	Response Type
1. One-year pregnancy risk for teenager	73%	23%	Risk %
2. Theoretical effectiveness of birth control			
Abstinence	1.15	0.86	Rank
Depo-provera	2.53	0.96	Rank
Birth control pills	2.62	0.55	Rank
Condoms	3.59*	0.96	Rank
Diaphragm	3.68*	0.81	Rank
Withdrawal	5.32*	0.59	Rank
3. Infection risk for sexually active teenager			
HPV	2.09	1.16	Rank
Chlamydia	1.55	0.62	Rank
Gonorrhea	2.70	1.10	Rank
Syphilis	4.42	0.75	Rank
HIV or AIDS	4.15	0.67	Rank
4. Who is at greater risk of STI?			
Suzy had 12 partners	15%	N/A	Choice %
Juanita's boyfriend had 12 partners	3%	N/A	Choice %
Same risk for Suzy and Juanita	82%	N/A	Choice %
5. Juanita is at no risk because boyfriend is monogamous			
True	0%	N/A	Choice %
False	100%	N/A	Choice %

the professionals are wrong. Differences might be justified by differences in local populations or by shortcomings in published studies. However, there is no evidence supporting such explanations, and any differences from published estimates remain troubling.

As expected, the rank ordering of birth control methods conformed to published data suggesting that theoretical effectiveness (from most to least effective) is perceived as follows: abstinence (defined as "no sexual activity"), Depo-provera, birth control pills, condoms, diaphragm, and withdrawal (e.g., Fu *et al.*, 1999; Trussell *et al.*, 1995; Trussell & Vaughn, 1999). Depo-provera and birth control pills were indistinguishable for each of the groups, and most also ranked condoms and the diaphragm similarly (and as less effective than Depo-provera and pills). However, the workshop group ranked condoms as theoretically more highly effective than the diaphragm.

The ordering of risk of transmission for different organisms was seen as similar across groups, with the exception of the other health care professionals, who perceived chlamydia to be more likely to be contracted than HPV. The typical ordering was HPV or chlamydia (which were generally indistinguishable), followed by gonorrhea, followed by syphilis or HIV/AIDS (which were also similar). This ordering agrees roughly with published data (but see discussion about HPV below (Bunnell *et al.*, 1999); Division of STD Prevention, 1998). Because rates of syphilis relative to HIV/AIDS vary geographically, and the latter is more prevalent than the former in Arizona (Mrela & Jimemenez, 1998), it is interesting to note that group differences in ranks just missed significance according to analysis of variance, $F(3,168) = 2.55$, $p < 0.06$ (the effect size is not large, $\eta^2 = 0.0436$, and the power to detect this effect size with $\alpha = 0.05$ is only 0.6325). The national workshop group ranked HIV/AIDS as least likely to be contracted at 4.61 (which is characteristic of most areas), whereas the local health care professionals ranked it at 4.15. The other two groups' mean rankings fell in between these estimates. (Statistical analyses of the other

Table V. Questionnaire Responses for Medical and Graduate Students Attending Grand Rounds in Internal Medicine, Emergency Medicine, Adolescent Pediatrics, and Public Health

Question	Mean	*SD*	Response Type
1. One-year pregnancy risk for teenager	77%	18%	Risk %
2. Theoretical effectiveness of birth control			
Abstinence	1.00	0.00	Rank
Depo-provera	2.97	1.17	Rank
Birth control pills	2.91	1.08	Rank
Condoms	3.82*	1.14	Rank
Diaphragm	4.09*	1.03	Rank
Withdrawal	5.62*	0.89	Rank
3. Infection risk for sexually active teenager			
HPV	1.94	1.20	Rank
Chlamydia	1.85	0.78	Rank
Gonorrhea	2.71	1.00	Rank
Syphilis	3.88	1.12	Rank
HIV or AIDS	4.44	0.66	Rank
5. Who is at greater risk of STI?			
Suzy had 12 partners	38%	N/A	Choice %
Juanita's boyfriend had 12 partners	3%	N/A	Choice %
Same risk for Suzy and Juanita	59%	N/A	Choice %
6. Juanita is at no risk because boyfriend is monogamous			
True	0%	N/A	Choice %
False	100%	N/A	Choice %

disease rankings would not be worthwhile because ranking are contingent on one another and these would, therefore, not represent independent tests.)

Although respondents ranked HPV and chlamydia similarly (or HPV below chlamyida), studies comparing HPV prevalence to other STIs generally report much higher rates for HPV. For example, Burk *et al.* (1996) detected HPV DNA in 27.8% of a sample of 604 college women. Similar results were found in another sample of 608 college women. HPV prevalence at baseline was found to be 26% (the cumulative 36-month incidence was 43%; Ho *et al.*, 1998). In contrast, in the Burk *et al.* study, 2.1% of 338 subjects tested for chlamydia were positive, 0.2% of 570 were positive for gonorrhea, and 0.2% of 497 were positive for syphilis. Recent data collected by Koutsky (reported in Jancin, 1999) showed a similar pattern for 600 female college freshman at the University of Washington. At enrollment, 28% had HPV, none had gonorrhea, and 0.9% had chlamydia. (The seroprevalence of antibodies to herpes simplex virus type 2 was 2.6%.)

Given the predominance of HPV over chlamydia and other STIs in recent studies, we conducted a one-sample *t*-test for each group separately comparing observed rankings for HPV to a theoretical ranking of 1.0. In other words, we determined whether each group's ranking differed significantly from the value suggested in the literature, specifically that risk of infection was highest for HPV. Each group's ranking differed significantly from the target value: for the workshop group, $t(22) = 3.23$, $p < 0.005$; for the physicians, $t(81) = 6.03$, $p < 0.001$; for the other health care professionals, $t(32) = 5.42$, $p < 0.001$; and for the students, $t(33) = 4.56$, $p < 0.001$. (Means and standard deviations are displayed in Tables II–V.) An analysis of variance did not detect differences in rankings for HPV across groups. We should point out that national data comprehensively comparing HPV prevalence to other STIs is not yet available, which is one reason for our selection of a ranking task rather than point estimates. Although exact prevalence rates for HPV and most other STIs assessed within the same sample are difficult to obtain, recent studies suggest that HPV is ranked first in prevalence when compared to other STIs. As predicted, health care professionals' rankings did not reflect these recent findings regarding HPV.

We also predicted effects of knowledge on questions that concerned risks associated with sexually transmitted infection, including gender differences in biological susceptibility and risks associated with direct versus indirect exposure to multiple partners (Division of STD Prevention, 1998; Holmes *et al.*, 1999). Specifically, research has shown greater biological susceptibility in females for sexually transmitted infections. Similarly, if a woman is exposed directly to multiple sexual partners she is at greater risk of infection than if she is exposed indirectly through a male to the same number of partners. The male, having lower biological susceptibility, is less likely to be a vector for infection to his partner (all other factors being equal). (However, one might counter that the male had been directly exposed to multiple female partners, whereas the female had been directly exposed to less susceptible males.) Thus, although the answer to the question concerning gender differences in biological susceptibility is straightforward given the literature, the question concerning multiple partners is not. We expected groups to differ on these questions according to level of training. Although such information is covered in advanced training, subjects lacking specialized knowledge would not necessarily be expected to be aware of these subtleties in the published literature.

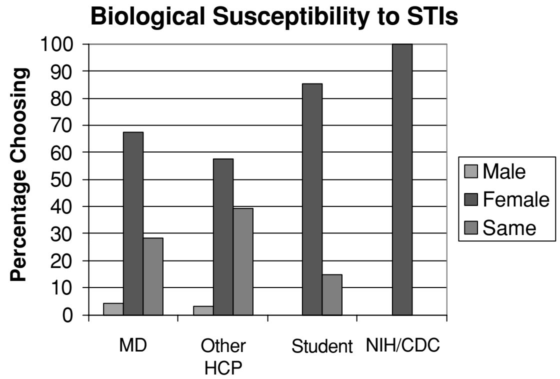

Fig. 1. Judgments of biological susceptibility to STIs in males versus females.

For the question regarding biological susceptibility, we conducted a chi-square analysis comparing frequencies of selecting the responses "men," "women," or "same" level of risk across the four groups. The chi-square was significant, $\chi^2(9) = 20.97$, $p < 0.02$, indicating that groups differed in their responses. As shown in Fig. 1, 100% of the workshop group selected the correct response of "women," followed by students (with a surprisingly high percentage correct), physicians, and other health care professionals. For the question concerning multiple partners, most respondents indicated that the risk of infection was the same for a woman exposed directly to multiple sexual partners as for a woman exposed indirectly through a male to the same number of partners. Although the workshop group was almost equally divided between "same" risk and direct exposure being riskier, the smaller sample size in that group worked against observing significant group differences. Virtually all respondents agreed that indirect exposure was still risky, despite a partner's claims of monogamy (e.g., Joffee *et al.*, 1992).

Subsequent questions were designed to determine whether professionals would provide risk estimates that differed appreciably from new research indicating that infection (e.g., Burk *et al.*, 1996; Ho *et al.*, 1998; Jancin, 1999) and re-infection rates (Fortenberry *et al.*, 1999; Orr *et al.*, 1999, 2001) for teenage girls are substantially higher than previously estimated. Like the prevalence rates for HPV, this information has not yet been widely disseminated among professionals. Regarding re-infection risk for STIs, Fortenberry *et al.* (1999) found that 40% of adolescent girls diagnosed with STIs were subsequently re-infected within a year. More recently, however, Orr *et al.* (1999, 2001) reported a re-infection rate of 74% for urban adolescent girls within seven months, and 46% of their male contacts also had an STI at seven months. Therefore, using a one-sample t-test, we compared risk estimates to both a target value of 40% and one of 74% for the question concerning teenage girls and to a value of 46% for the question about their male contacts.

Using the lower estimate of 40%, we found significant overestimation for physicians, other health care professionals, and students: $t(80) = 5.09$, $p < 0.001$; $t(33) = 4.28$, $p < 0.001$; $t(33) = 3.93$, $p < 0.001$, respectively. However, we should note that the Fortenberry *et al.* study did not test adolescents for all STIs (only for chlamydia, gonorrhea, and trichomonas), suggesting that 40% could be an underestimate of overall re-infection risk. (Group differences did not achieve significance with analysis of variance.) Using the higher estimate of 74%, all groups were found to significantly underestimate the risk of re-infection: for the workshop group, $t(21) = -6.27$, $p < 0.001$; for the physicians, $t(80) = -11.73$, $p < 0.001$; for the other health care professionals, $t(33) = -5.55$, $p < 0.001$; and for the students, $t(33) = -4.07$, $p < 0.001$ (see Fig. 2). In short, except for the workshop group, risk estimates were both higher than the 40% target value and lower than the 74% target value (e.g., for physicians, the 95% confidence interval did not contain either 40% or 74%.) Estimates of re-infection risk for males' contacts were not found to differ significantly from 46%, except for health care professionals, $t(32) = 2.37$, $p < 0.03$, who slightly overestimated the risk.

Regarding infection risk, the most recent research found that young women's risk of acquiring an HPV infection alone jumped by 50% with each new sexual partner (Jancin, 1999). Therefore, we compared risk estimates to a conservative estimate of infection of 50% using a one-sample t-test. (The estimate is con-

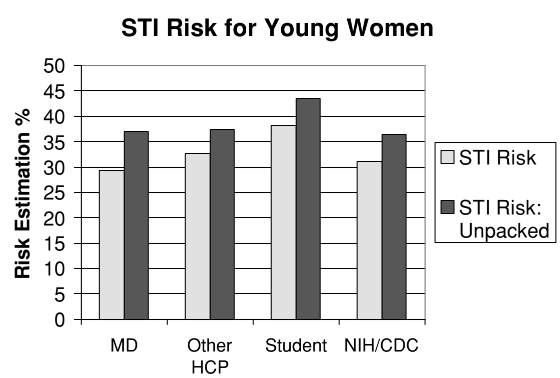

Fig. 2. Estimations of re-infection risk for young women.

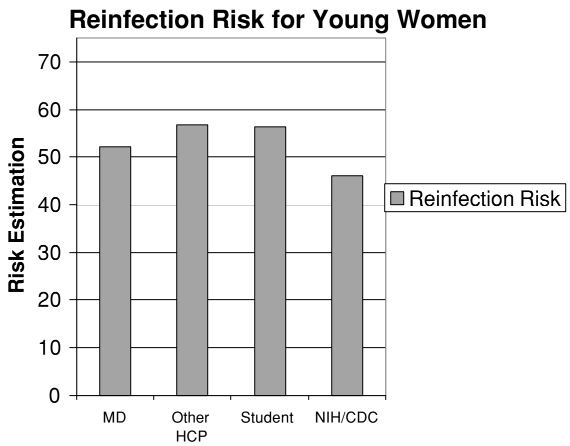

Fig. 3. Estimations of STI risk for young women: packed versus unpacked.

servative because it does not include all STIs.) Each groups' risk estimates differed significantly from 50%: for the workshop group, $t(20) = -4.36$, $p < 0.001$; for the physicians, $t(79) = -13.20$, $p < 0.001$; for the other health care professionals, $t(33) = -3.32$, $p < 0.003$; and for the students, $t(33) = -3.20$, $p < 0.004$. As shown in Fig. 3, each of these groups significantly underestimated the risk of infection with each new sexual partner. (The groups' estimates did not differ significantly from one another.)

We also compared risk estimates for the "unpacked" version of the question about how much a young woman's risk of contracting a sexually transmitted infection jumps with each new sexual partner. Specifying STIs was designed to increase risk estimates by cuing subjects to retrieve more information. For this version of the question, students' estimates no longer differed significantly from the target value of 50%. The remaining groups continued to differ from 50%, although their estimates did increase (see below): for the workshop group, $t(19) = -3.20$, $p < 0.006$; for the physicians, $t(78) = -7.47$, $p < 0.001$; and for the other health care professionals, $t(31) = -2.73$, $p < 0.02$.

To determine whether "unpacking" produced significantly higher risk estimates than the global or unspecified version, we performed a repeated-measures analysis of variance on the risk estimates for the two comparable questions with group as a factor. The repeated measure of "unpacking" had a significant effect in increasing risk estimates, $F(1,161) = 13.66$, $p < 0.001$. As Fig. 3 illustrates, there was no interaction with group. The increase in estimates was similar across all four groups.

The results we have discussed thus far concerning risk estimation have implications for CDC risk communication and FDA product labeling. As we have seen, subjects underestimated the risk of HPV, which is transmitted through skin-to-skin contact. If subjects are underestimating the risk of infection at least partly because they focus on the gist of STIs as fluid-borne, then they should overestimate the effectiveness of condoms in risk reduction. Risk reduction with condoms for fluid-borne HIV, for example, is estimated at 87% (Anonymous, 1993; Davis & Weller, 1999). The CDC and FDA statements refer to herpes, which is transmitted through skin-to-skin contact as well as by fluids (and the FDA statement refers to genital warts, which is one manifestation of HPV infection; Wen, 1999). However, research is lacking concerning the effectiveness of condoms in reducing risk of infection with herpes, syphilis, and trichomonas. (One study, published after these professionals' judgments were obtained, indicates risk reduction for herpes type 2 infection associated with condom use for women but not for men (Wald, *et al.*, 2001.)) Estimates for risk reduction with gonorrhea have ranged from 0–34% for women and 74–100% for men (e.g., Austin, 1984; Barlow, 1977; Hooper, *et al.*, 1978; Pemberton *et al.*, 1972; Rosenberg *et al.*, 1992). Risk reduction estimates are lower for chlamydia (Gaydos *et al.*, 1998; Joesoef *et al.*, 1997; Ramstedt *et al.*, 1992; Schwartz *et al.*, 1997; Zelin *et al.*, 1995). Thus, the literature does not pinpoint a single value that captures overall risk reduction for the STIs and their sequelae identified in the CDC and FDA statements.

For the sake of illustration, we compared risk reduction estimates for condoms based on the CDC and FDA statements to 50% using a one-sample *t*-test. As shown in Figs. 4 and 5, risk reduction estimates significantly exceeded 50% for all groups for both questions. For the CDC question, for the workshop group, $t(16) = 3.70$, $p < 0.003$; for the physicians, $t(78) = 11.89$, $p < 0.001$; for the other health care professionals, $t(31) = 11.14$, $p < 0.001$; and for the students, $t(32) = 16.90$, $p < 0.001$. For the FDA question, for the workshop group, $t(17) = 4.36$, $p < 0.001$; for the physicians, $t(76) = 12.48$, $p < 0.001$; for the other health care professionals, $t(31) = 13.42$, $p < 0.001$; and for the students, $t(33) = 21.12$, $p < 0.001$. Groups differed significantly for both the CDC question, $F(3,157) = 2.92$, $p < 0.04$, and the FDA question, $F(3,157) = 4.14$, $p < 0.008$. Tukey HSD tests showed that, for the CDC

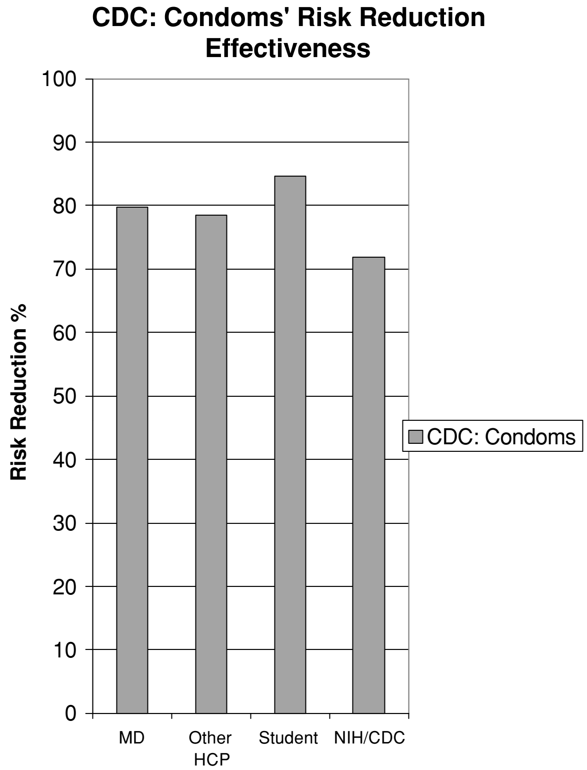

Fig. 4. Interpretations of CDC statements about condoms' effectiveness in risk reduction.

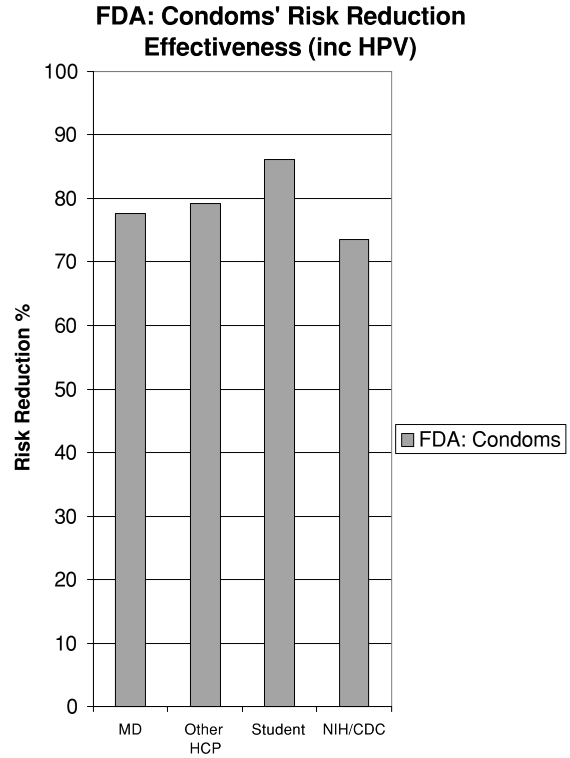

Fig. 5. Interpretations of FDA statements about condoms' effectiveness in risk reduction.

and FDA statements, students overestimated risk reduction for condoms more than physicians and more than the workshop group.

Finally, to assess processing interference independently of specific disease knowledge or meaningful gist, we asked professionals to make a common clinical judgment (post-test probability of disease), but did not specify the disease. The information contained in the question was sufficient, in principle, to answer the question correctly. Group differences were not predicted, specifically because disease knowledge was not relevant. Fig. 6 shows the percentage correct choice of the post-test probability of infection. Although it appears that the workshop group was superior to the others, their level of correct choices was around chance (50%). The remaining groups chose the correct response at lower than chance levels. A chi-square test comparing frequencies across groups was not significant. Table VI shows the mean percentage correct for the identical question for three groups of undergraduate students, as well as confidence ratings, and also shows the results for physicians. As

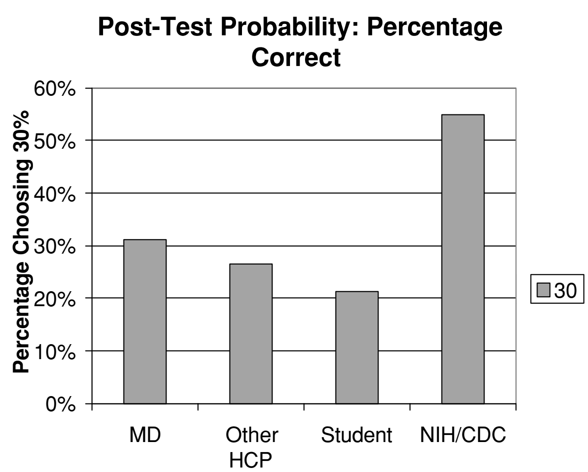

Fig. 6. Percentage correct choice of post-test probability of infection.

can be seen from Table VI, physicians and students were similarly poor at estimating post-test probability of disease, but physicians were more confident in their judgments.

Table VI. Percentage Choosing Correct Post-Test Probability of Infection and Confidence Rating for Undergraduates and Physicians

	Groups of Undergraduates and MDs			
	Psych. $N = 107$	Chem. $N = 84$	Mex-Amer. $N = 46$	MDs $N = 82$
% correct	45	40	36	31
Confidence (1–7 scale)	2.5	3.4	2.0	4.2

4. CONCLUSIONS

The aim of this study was to investigate health care professionals' biases in risk estimation for sexually transmitted infections (STIs), separating biases caused by knowledge deficits from those caused by representational biases, retrieval failures, and processing errors. Knowledge deficits were predicted to produce underestimation of transmission risk for human papillomavirus (HPV) in sexually active youth (especially females), re-infection rates, and gender differences in biological susceptibility. Further, we expected retrieval deficits to produce greater risk underestimation when STIs were not specified. Representational biases were predicted to produce overestimation of condom effectiveness. Last, we expected processing deficits to produce biases in post-test estimation of infection, regardless of knowledge. Each of these difficulties hampers the ability of health care professionals to accurately convey risk information to the public.

To summarize the results, health care professionals in all groups underestimated STI risk for sexually active youth (especially HPV), re-infection rates, and biological susceptibility in females, but overestimated effectiveness of condoms in reducing such risks. Risk estimates differed significantly from published estimates. These results are consistent with the assumptions of fuzzy-trace theory that risk estimates are based on imprecise, qualitative gist that reflects health care professionals' concepts of typical STIs (i.e., fluid-borne diseases) producing risk underestimation associated with atypical category members (e.g., HPV). Similarly, although CDC and FDA statements concerning condom effectiveness apply primarily to fluid-borne disease, estimates of risk reduction generalized (inappropriately) to skin-to-skin transmission, as in HPV.

We predicted that risk underestimation of STIs could be reduced by providing specific retrieval cues to relevant knowledge. Consistent with this prediction, significant differences in risk estimates were obtained when STIs were specified (i.e., when the question "unpacked" the category of STIs by listing examples) rather than being described globally. Providing specific retrieval cues for stored knowledge significantly increased risk estimates for all groups (physicians, other health care professionals, medical and graduate students, and experts attending a national workshop on risk and STIs).

Finally, also as predicted by fuzzy-trace theory, professionals in all groups were subject to processing biases; only 31% overall selected the correct post-test probability of infection given a positive test result. Correct responses for all groups were below chance (i.e., <50% correct), except for those attending a national workshop sponsored by the National Institutes of Health and the Centers for Disease Control and Prevention. The latter group performed at chance. As predicted, level of training was not a factor in this kind of judgment error.

These errors in risk estimation are attributable to knowledge deficits, representational interference from inappropriate gist (fluid-borne STIs), failure to retrieve known facts about STIs, and interference from processing of overlapping classes (those with a positive test and those with disease). Judgments focus on the gist of classes, producing neglect of nongist classes and, thus, of overall risk estimates for STIs. Similar factors operate in other risk communication contexts, such as those involving genetic risks, informed consent for surgery, risk of heart attack, and nuclear power accidents (e.g., Lloyd, Reyna, & Whalen, 2001; Reyna, Lloyd, & Brainerd, in press; Reyna & Hamilton, 2001; Stone, Parker, & Yates, 1994). For example, the major cause of death for women is cardiovascular disease, but the gist of the category of "victims of heart disease" is older men, producing underestimation of women's risk. Processing interference is illustrated when relative and absolute risks of accidents are confused with one another (Reyna & Brainerd, 1993; Stone, Yates, & Parker, 1994), or when the risk of getting breast cancer given a genetic mutation is confused with the risk of having a genetic mutation given that one has breast cancer (Reyna, Lloyd, & Whalen, 2001; Wolfe, 1995). Fuzzy-trace theory also identifies developmental differences in these factors that have been used to explain adolescents' risky sexual decision making (Reyna *et al.*, in press; Reyna & Ellis, 1994).

Much of risk communication focuses on increasing the amount and accessibility of knowledge (e.g., proliferating websites). The present results point up the limitations of that strategy. Although risk underestimation, especially for HPV, can be linked to professionals' knowledge of a rapidly changing literature, knowledge deficits do not fully explain risk underestimation of STIs because providing better retrieval cues was sufficient to increase estimates. Knowledge also cannot explain processing biases in post-test estimation of disease because such questions did not require specific disease knowledge. (Information about prevalence rate, sensitivity, specificity, and the diagnostic test result was directly provided.) Hence, interventions designed to improve risk estimation among professionals must incorporate more than knowledge dissemination. They should also provide support for effective retrieval and accurate processing.

ACKNOWLEDGMENTS

This study was supported in part by grants from the National Institutes of Health (NIH 316201 and P50 AT00008), the Academic Medicine and Managed Care Forum, the National Science Foundation (SBR973-0143), and the United States Department of Commerce (SUB005).

APPENDIX

1. What is the risk of a teenager getting pregnant or getting someone pregnant if he or she has sex over a one-year time period and doesn't use anything for birth control?

0 . . 10 . . 20 . . 30 . . 40 . . 50 . . 60 . . 70 . . 80 . . 90 . . 100%

2. Rank order the theoretical effectiveness from most effective to least effective the following forms of birth control.

Condoms, birth control pills, withdrawal, abstinence, diaphragm, Depo-Provera (injectable):

Number from 1–6 where 1 equals most effective and 6 equals least effective.

—— Abstinence (no sexual activity)
—— Birth control pills
—— Condoms
—— Depo-Provera (injectable)
—— Diaphragm
—— Withdrawal

3. Rank order the use effectiveness (typical use) from most effective to least effective of the following forms of birth control.

Condoms, birth control pills, withdrawal, abstinence, diaphragm, Depo-Provera (injectable):

Number from 1–6 where 1 equals most effective and 6 equals least effective.

—— Abstinence (no sexual activity)
—— Birth control pills
—— Condoms
—— Depo-Provera (injectable)
—— Diaphragm
—— Withdrawal

4. Rank order the risk a sexually active teenager would have of contracting the following sexually transmitted infections, Human Papillomavirus, gonorrhea, Chlamydia, syphilis, and Human Immunodeficiency Virus (HIV or AIDS), from most likely to be contracted to least likely to be contracted where 1 is the most likely to be contracted and 5 is the least likely to be contracted.

—— Chlamydia
—— Gonorrhea
—— HIV or AIDS
—— Human Papillomavirus
—— Syphilis

5. Which sex is biologically more susceptible to contracting a sexually transmitted infection when they have sex with someone who is already infected?

—— Men
—— Women
—— They have about the same risk

6. Suzy is 16 years old and is a high school drop out. She dresses like a "hootchie-Mama." Suzy has been having sex for a year (since she was 15). She admits that she has "slept around" and has had sex with 12 different guys. She comes to the doctor for a routine check-up.

Juanita is 16 years old and attends high school. She is deeply religious and quite shy. She has had one steady boyfriend, Jorge, and they have been going together for a year. Juanita and Jorge are sexually active, but they plan to be married in six months. Jorge used to be a player (he has had sex with a dozen former girlfriends). However, Jorge has been completely faithful to Juanita. She comes to the doctor for a routine check-up.

Assume that everything said about Suzy and Juanita is TRUE and that everything not mentioned here is the SAME for both Suzy and Juanita.

At the time of routine check-up who is at greater risk of having a sexually transmitted disease?

Check one:

—— Suzy
—— Juanita
—— They have about the same risk

7. Juanita thinks she is at no risk of contracting a sexually transmitted infection because Jorge is completely faithful to her. Juanita's perception of her risk is accurate.

—— True
—— False

8. A young woman's risk of contracting a sexually transmitted infection, including Human Papillomavirus (HPV), jumps by
0..10..20..30..40..50..60..70..80..90..100%
with each new sexual partner.

9. An urban teenage girl had a sexually transmitted infection 7 months ago and was treated. She continues to be sexually active. What is the risk that she has another STI now?
0..10..20..30..40..50..60..70..80..90..100%

10. An urban teenage female had a sexually transmitted infection 7 months ago and she was treated. She continues to be sexually active. What is the risk that her male contact has another STI now?
0..10..20..30..40..50..60..70..80..90..100%

11. A young woman's risk of contracting any of the following: Human Papillomavirus (HPV) or HIV or chlamydia, or genital herpes, or syphilis or gonorrhea jumps by
0..10..20..30..40..50..60..70..80..90..100%
with each new sexual partner.

12. Suppose condoms are 90% effective in reducing the risk for sexual transmission of disease X and 70% effective in reducing the risk for disease Y. (Disease X and disease Y are equally common.) Then condoms would be 70% effective in reducing the risk of transmission for **any** of these diseases.

The Centers for Disease Control and Prevention (CDC) have stated that, "Condom use reduces the risk for gonorrhea, herpes simplex virus (HSV) infection, genital ulcers, and pelvic inflammatory disease. In addition, intact latex condoms provide a continuous mechanical barrier to HIV, HSV, hepatitis B virus, *Chlamydia trachomatis*, and *Neisseria gonorrhoea.*"

This means that when used consistently and correctly condoms are
0..10..20..30..40..50..60..70..80..90..100%
effective in reducing the risk for getting any of these diseases.

13. FDA package labeling on some condoms says the following, "If used properly, latex condoms will help to reduce the risk of transmission of HIV infection (AIDS) and many other sexually transmitted diseases, including chlamydia, genital herpes, genital warts, gonorrhea, hepatitis B, and syphilis" (Trojan-enz package label).

This means that when used consistently and correctly condoms are
0..10..20..30..40..50..60..70..80..90..100%
effective in reducing the risk of transmission of HIV infection (AIDS) and many other sexually transmitted infections, including chlamydia, genital herpes, genital warts, gonorrhea, hepatitis B, and syphilis.

14. Suppose the prevalence of Disease X in the population in general is 10%. A doctor performs a diagnostic test, which has a sensitivity of 80% (80% of those who actually have the disease will have a positive result) and a specificity of 80% (80% of those who actually do not have the disease will have a negative result). The test result is positive. What is the probability of disease?

Check one:

—— 30%
—— 70%

How confident are you about this probability judgment? Check one rating from the 1–7 scale below:

—— 1 = No confidence at all (guess)
—— 2 = Very low confidence
—— 3 = Low confidence
—— 4 = Medium confidence
—— 5 = High confidence
—— 6 = Very high confidence
—— 7 = Complete confidence

REFERENCES

Anonymous. (1993). Update: Barrier protection against HIV infection and other sexually transmitted diseases. *Morbidity and Mortality Weekly Report*, *42*(30), 589–591.

Austin, H., Louv, W. C., & Alexander, W. J. (1984). A case-control study of spermicides and gonorrhea. *Journal of the American Medical Association*, *251*, 2822–2824.

Barlow, D. (1977). The condom and gonorrhoea. *Lancet*, *222*, 811.

Brainerd, C. J., & Reyna, V. F. (1990). Inclusion illusions: Fuzzy-trace theory and perceptual salience effects in cognitive development. *Developmental Review*, *10*, 365–403.

Brainerd, C. J., Reyna, V. F., & Mojardin, A. H. (1999). Conjoint recognition. *Psychological Review*, *106*, 160–179.

Bunnell, R. E., Dahlberg, L., Rolfs, R., Ransom, R., Gershman, K., Farshy, C., Newhall, W. J., Schmid, S., Stone, K., & St. Louis, M. (1999). High prevalence and incidence of sexually transmitted diseases in urban adolescent females despite

moderate risk behavior. *Journal of Infectious Diseases*, *180*(5), 1624–1631.
Burk, R. D., Ho, G. Y., Beardsley, L., Lempa, M. L., Peters, M., & Bierman, R. (1996). Sexual behavior and partner characteristics are the predominant risk factors for genital human papillomavirus infection in young women. *Journal of Infectious Diseases*, *174*, 679–689.
Davis, K. R., & Weller, S. C. (1999). The effectiveness of condoms in reducing heterosexual transmission of HIV. *Family Planning Perspectives*, *31*(6), 272–279.
Division of STD Prevention. (September 1998). *Sexually transmitted disease surveillance, 1997*. U.S. Department of Health and Human Services. Atlanta, GA: Centers for Disease Control and Prevention (CDC).
Division of STD Prevention. (December 1999). *Prevention of genital HPV infection and sequelae: Report of an external consultants' meeting*. Department of Health and Human Services. Atlanta, GA: Centers for Disease Control and Prevention (CDC).
Epstein, S. (1994). Integration of the cognitive and psychodynamic unconscious. *American Psychologist*, *49*, 709–724.
Fortenberry, J. D., Brizendine, E. J., Katz, B. P., Wools, K. K., Blythe, M. J., & Orr, D. P. (1999). Subsequent sexually transmitted infections among adolescent women with genital infection due to Chlamydia trachomatis, Neisseria gonorrhoea, or Trichomonas vaginalis. *Sexually Transmitted Diseases*, *26*(1), 26–32.
Fu, H., Darroch, J. E., Haas, T., & Tanjit, N. (1999). Contraceptive failure rates: New estimates from the 1995 national survey of family growth. *Family Planning Perspectives*, *31*(2), 60, Table 1.
Gaydos, C. A., Howell, M. R., Pare, B., Clark, K. L., Ellis, D. A., Hendrix, R. M., Gaydos, J. C., McKee, K. T. Jr., & Quinn, T. C. (1998). Chlamydia trachomatis infections in female military recruits. *New England Journal of Medicine*, *339*, 739–744.
Ho, G. Y., Bierman, R., Beardsley, L., Chang, J., & Burk, R. D. (1998). Natural history of cervicovaginal papillomavirus infection in young women. *New England Journal of Medicine*, *338*(7), 423–428.
Holmes, K., Sparling, P. F., Mardh, P. A., Lemon, S. M., Stamm, W., Piot, P., & Wasserheit, J. N. (1999). *Sexually transmitted diseases*. New York: McGraw Hill.
Hooper, R. R., Reynolds, G. H., Jones, O. G., Zaidi, A., Wiesner, P. J., Latimer, K. P., Lester, A., Campbell, A. F., Harrison, W. O., Karney, W. W., & Holmes, K. K. (1978). Cohort study of venereal disease: The risk of gonorrhea transmission from infected women to men. *American Journal of Epidemiology*, *108*(2), 136–144.
Jancin, B. (1999). Genital HPV most common STD in college women. *Pediatric News*, November, 19.
Joesef, M. R., Linnan, M., Barakbah, Y., Idajadi, A., Kambodji, A., & Schulz, K. (1997). Patterns of sexually transmitted diseases in female sex workers in Surabaya, Indonesia. *International Journal of STD & AIDS*, *8*, 576–580.
Joffee, G. P., Foxman, B., Schmidt, A. J., Farris, K. B., Carter, R. J., Neumann, B. S., Tolo, K., & Walters, A. M. (1992). Multiple partners and partner choice as risk factors for sexually transmitted diseases among female college students. *Sexually Transmitted Diseases*, *19*(5), 272–278.
Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.
Kintsch, W. (1974). *The representation of meaning in memory*. Hillsdale, NJ: Erlbaum.
Lloyd, F., Reyna, V. F., & Whalen, P. (2001). Accuracy and ambiguity in counseling patients about genetic risk. *Archives of Internal Medicine*, *161*, 2411–2413.
Mrela, C. K., & Jimenez, J. (1998). *The 1998 Arizona health status and vital statistics annual report*. Phoenix, Arizona: Office of Epidemiology and Statistics, Bureau of Public Health Statistics, Arizona Department of Health Services.
Orr, D. P., Brizendine, E. J., Fortenbery, J. D., & Katz, B. P. (1999). Subsequent sexually transmitted infections (STI) among high risk adolescents: Is it time to reexamine screening guidelines? Abstract presented at the 13th International Society for Sexually Transmitted Diseases Research. Denver, CO.
Orr, D. P., Johnston, K., Brizendine, E. J., Katz, B. P., & Fortenbery, J. D. (2001). Subsequent sexually transmitted infection in urban adolescents and young adults. *Archives of Pediatrics and Adolescent Medicine*, *155*, 947–953.
Pemberton, J., McCann, J. S., Mahony, J. D., MacKenzie, G., Dougan, H., & Hay, I. (1972). Socio-medical characteristics of patients attending a V.D. clinic and the circumstances of infection. *British Journal of Venereal Disease*, *48*, 391–396.
Peyton, C. L., Gravitt, P. E., Hunt, W. C., Hundley, R. S., Zhao, M., Apple, R. J, & Wheeler, C. M. (2001). Determinants of genital human papillomavirus detection in a U.S. population. *Journal of Infectious Diseases*, *183*, 1554–1564.
Ramstedt, K., Forssman, L., Giesecke, J., & Granath, F. (1992). Risk factors for *chlamydia trachomatis* infection in 6810 young women attending family planning clinics. *International Journal of STD & AIDS*, *1992*(3), 117–122.
Reyna, V. F. (1991). Class inclusion, the conjunction fallacy, and other cognitive illusions. *Developmental Review*, *11*, 317–336.
Reyna, V. F. (1995). Interference effects in memory and reasoning: A fuzzy-trace theory analysis. In F. N. Dempster & C. J. Brainerd (Eds.), *New perspectives on interference and inhibition in cognition* (pp. 29–61). New York: Academic Press.
Reyna, V. F. (1996a). Conceptions of memory development, with implications for reasoning and decision making. *Annals of Child Development*, *12*, 87–118.
Reyna, V. F. (1996b). Meaning, memory and the interpretation of metaphors. In J. Mio & A. Katz (Eds.), *Metaphor: Implications and applications* (pp. 39–57). Hillsdale, NJ: Erlbaum.
Reyna, V. F. (2000). Data, development, and dual processes in rationality. *Behavioral and Brain Sciences*, *23*, 694–695.
Reyna, V. F., Adam, M. B., Walsh, M. E., LeCroy, C. W., Muller, K. L., & Brainerd, C. J. (In press). The development of judgment and decision-making from childhood through adolescence. Invited chapter for J. Jacobs & P. Klacynski (Eds.), *The development of children's and adolescents' judgment and decision-making*.
Reyna, V. F., & Brainerd, C. J. (1991a). Fuzzy-trace theory and children's acquisition of scientific and mathematical concepts. *Learning and Individual Differences*, *3*, 27–60.
Reyna, V. F., & Brainerd, C. J. (1991b). Fuzzy-trace theory and framing effects in choice: Gist extraction, truncation, and conversion. *Journal of Behavioral Decision Making*, *4*, 249–262.
Reyna, V. F., & Brainerd, C. J. (1992). A fuzzy-trace theory of reasoning and remembering: Paradoxes, patterns, and parallelism. In A. Healy, S. Kosslyn, & R. Shiffrin (Eds.), *From learning processes to cognitive processes: Essays in honor of William K. Estes* (vol. 2, pp. 235–259). Hillsdale, NJ: Erlbaum.
Reyna, V. F., & Brainerd, C. J. (1993). Fuzzy memory and mathematics in the classroom. In G. M. Davies & R. H. Logie (Eds.), *Memory in everyday life* (pp. 91–119). Amsterdam: North-Holland.
Reyna, V. F., & Brainerd, C. J. (1994). The origins of probability judgment: A review of data and theories. In G. Wright & P. Acton (Eds.), *Subjective probability* (pp. 239–272). New York: Wiley.
Reyna, V. F., & Brainerd, C. J. (1995a). Fuzzy-trace theory: An interim synthesis. *Learning and Individual Differences*, *7*, 1–75.
Reyna, V. F., & Brainerd, C. J. (1995b). Fuzzy-trace theory: Some foundational issues. *Learning and Individual Differences*, *7*, 145–162.

Reyna, V. F., & Brainerd, C. J. (1998). Fuzzy-trace theory and false memory: New frontiers. *Journal of Experimental Child Psychology*, *71*, 194–209.
Reyna, V. F., & Ellis, S. C. (1994) Fuzzy-trace theory and framing effects in children's risky decision making. *Psychological Science*, *5*, 275–279.
Reyna, V. F., & Hamilton, A. J. (2001). The importance of memory in informed consent for surgical risk. *Medical Decision Making*, *21*, 152–155.
Reyna, V. F., & Kiernan, B. (1994). The development of gist versus verbatim memory in sentence recognition: Effects of lexical familiarity, semantic content, encoding instruction, and retention interval. *Developmental Psychology*, *30*, 178–191.
Reyna, V. F., & Kiernan, B. (1995). Children's memory and metaphorical interpretation. *Metaphor and Symbolic Activity*, *10*, 309–331.
Reyna, V. F., Lloyd, F. J., & Brainerd, C. J. (In press). Memory, development, and rationality: An integrative theory of judgment and decision making. In S. Schneider & J. Shanteau (Eds.), *Emerging perspectives on decision research*. New York: Cambridge University Press.
Reyna, V. F., Lloyd, F. J., & Whalen, P. (2001). Genetic testing and medical decision making. *Archives of Internal Medicine*, *161*, 2406–2408.
Rosenberg, M. J, Davidson, A. J., Chen, J. H., Judson, F. N., & Douglas, J. M. (1992). Barrier contraceptives and sexually transmitted diseases in women: A comparison of female-dependent methods and condoms, *American Journal of Public Health*, *82*(5), 669–674.
Schwartz, M. A., Lafferty, W. E., Hughes, J. P., & Handsfield, H. H. (1997). Risk factors for urethritis in heterosexual men. The role of fellatio and other sexual practices. *Sexually Transmitted Diseases*, *24*, 449–55.
Sloman, S. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin*, *119*, 3–22.
Slovic, P., & Peters, E. (1998). The importance of worldviews in risk perception. *Journal of Risk Decision and Policy*, *3*(2), 165–170.
Stone, E. R., Yates, J. F., & Parker, A. M. (1994). Risk communication: Absolute versus relative expressions of low-probability risks. *Organizational Behavior and Human Decision Processes*, *60*, 387–408.
Trussell, J., Hatcher, R. A., & Cates, W., *et al.* (1995). Contraceptive failure in the United States: An update. *American Health Consultants, Contraceptive Technology Update*, *17*(2), 13.
Trussell, J., & Vaughn, B. (1999). Contraceptive failure, method-related discontinuation and resumption of use: Results from the 1995 National Survey of Family Growth. *Family Planning Perspectives*, *31*(6), 64–72.
Tversky, A., & Koehler, D. (1994). Support theory: A nonextensional representation of subjective probability. *Psychological Review*, *101*, 547–567.
Wald, A., Langenberg, A. G., Link, K., Izu, A. E., Ashley, R., Warren, T., Tyring, S., Douglas, J. M. Jr., & Corey, L. (2001). Effect of condoms on reducing the transmission of herpes simplex virus type 2 from men to women. *Journal of the American Medical Association*, *285*(24), 3100–3106.
Wolfe, C. (1995). Information seeking on Bayesian conditional probability problems: A fuzzy-trace theory account. *Journal of Behavioral Decision Making*, *8*, 85–108.
Zelin, J. M., Robinson, A. J., Ridgway, G. L., Allason-Jones, E., & Williams, P. (1995). Chlamydial urethritis in heterosexual men attending a genitourinary medicine clinic: Prevalence, symptoms, condom usage, and partner change. *International Journal of STD & AIDS*, *6*, 27–30.