Applied & Preventive Psychology 7:77–94 (1998). Cambridge University Press. Printed in the USA.

Adolescent vulnerability: A framework for behavioral interventions

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Abstract

A general framework is offered for characterizing behavioral risks in a way that might help coordinate behavioral interventions. It is demonstrated in terms of adolescents' vulnerability, arising from the life situations confronting teens, from teens' understanding of those situations, and from the beliefs of those entrusted with helping them (parents, educators, psychologists, etc.). The framework provides a rationale for identifying opportunities to reduce adolescent vulnerability, based on research regarding the genesis and control of risks. It provides a common language for characterizing alternative theoretical approaches to these issues and a systematic way to integrate their results. It is illustrated with results from research on the role of information in determining adolescent vulnerability.

Key words: Adolescence, Invulnerability, Risk analysis, Infectious disease, Behavioral decision making

Vulnerability is a fact of life. Bad things can happen to any of us at any time. We may get sick. We may be hurt. We may not achieve our full potential. We may blow a great opportunity. Some of us are more vulnerable than others. We may be born with less robust bodies or in less favored social circumstances. We may find ourselves in the path of random violence or disease. Some of these special vulnerabilities may be reduced by special efforts, such as diet, exercise, and study. Vulnerabilities may also be created by our own hands, through substance abuse, carelessness, ignorance, and the like.

Responsible individuals do what they can reasonably to reduce their personal vulnerability. Responsible societies intervene on behalf of those with limited ability to protect themselves. Adolescents are a popular target of such interventions. Extensive (and often expensive) programs focus on threats to teens' health or academic achievement. These programs supplement the uncounted efforts of parents and others to provide such protection. These interventions are motivated by concern both for teens as individuals and for those who pay the bills when teens fail to become healthy, productive adults (Dryfoos, 1990).

The stakes riding on these interventions, obviously, are high (Office of Technology Assessment, 1991). When interventions fail, they not only waste the resources invested in them, but also crowd out alternative actions, which might have done more for teens. For example, when information-based interventions are ineffective they consume resources that could be used for more effective treatments (Botvin, Schinke, & Orlandi, 1995). In addition to the direct costs of implementing programs and the opportunity costs of not doing something better, there are social costs to ineffective programs. Teens may resent those they see as wasting their time and ignoring their real needs, while advertising themselves as "adolescent specialists." Those specialists may erode teens' trust in the adults' world more generally, if they subject teens to programs whose "information" is obviously slanted (e.g., addressing the risks, but not the benefits, of teens' activities).

Of course, part of the business of adolescence is learning to judge adults critically and to act independently. As a result, teens' disparaging remarks prove nothing by themselves, whether directed at public service announcements, health classes, guidance counselors, group treatments, designated-driver contracts, or teen curfews. Indeed, teens may dislike most, those programs that work best, by restricting their ability to have a good time or by calling them on myths that they would like to preserve (e.g., "I can tell when

This research was supported by the National Institute of Alcohol Abuse and Alcoholism and the National Institute of Allergies and Infectious Disease, and the National Science Foundation. We thank Bob Cook, Robyn Dawes, Hadi Dowlatabadi, Claire Palmgren, David Rubovits, and Rosa Stipanovic for their continuing contributions to the work. Particular thanks go to Willam Land, director of basic research at NIAAA, who stimulated some of the thinking here with a phone call, asking how his agency might use risk analysis to prioritize its research agenda. Craig Ewart, Granger Morgan, and Lisa Onken provided very helpful comments on an earlier draft. The views expressed are those of the authors.

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a party is about to get out of hand; when I have had too much to drink; when a sexual partner has chlamydia"). Nonetheless, teens' social consciousness may be attuned most acutely to how society treats them as a group. As a result, inept interventions (however well intended) may contribute to their general feelings of alienation.

Conversely, adults may despair of teens whom their interventions seemingly cannot reach or protect. These adults' frustrations may lead them to adopt increasingly disrespectful attitudes and coercive interventions. Like teens, adults may be driven by complex motives. Certainly, they want to protect the teens in their charge. However, they may also be threatened by those teens' growing independence or be reluctant to admit that the world does not really guarantee fame and fortune to young people who toe the line (do their homework, stay celibate, refrain from smoking, etc.). As a result, candid interventions may threaten adults' own myths of benificence and omnipotence. When programs fail, it may be easier for adults to blame their targets than their promoters.

Thus, poor programs deplete both teens' and adults' goodwill, furthering disaffection and distrust—and reducing the chances of success for future interventions. Given these high stakes, some systematic approach is needed for evaluating interventions. This article offers a behavioral-decision-theory approach to this task. It begins by considering the range of interventions that must be brought into a common evaluative framework. It then offers a model intended to accommodate them all. The model is illustrated by interpreting several prominent theories in the model's terms, by showing how it identifies potential sources (and controls) of vulnerability, and by describing some results from a research program reflecting its perspective. The article concludes with a general discussion of adolescent vulnerability.

Developing a Framework for Vulnerability

Identifying the Sources of Vulnerability

In principle, the "best" interventions are those with the greatest chance of changing something that will, in turn, make a desired difference. In this case, the needed difference is reducing teens' vulnerability. That might be achieved by changing the situations that confront teens, teens' understanding of those situations, or the understanding of those entrusted with teens' care. For example, adolescent sexuality creates clear risks to teens' health and development and to the welfare of any children that they might bear. Those risks might, in principle, be reduced by limiting teens' privacy (so that they have less opportunity for sex), by informing them about unfamiliar aspects of the risk (e.g., sexually transmitted diseases [STDs] that have received less attention as educators focus on acquired immunodeficiency syndrome [AIDS]), or by providing educators with a clearer picture of teens' fears and aspirations (so that they can provide more germane counsel and less risky ways to achieve desired ends).

In practice, however, these changes may not be possible and might not affect risk levels even when they can be implemented. To continue with the example: There may be little chance of restricting many teens' privacy. Moreover, if teens really want to have sex, then even fairly drastic privacy restrictions may not stop them; such furtive sex might even be more risky, insofar as teens are less able to control its circumstances. We may know so little about teens' risk beliefs that we cannot disabuse them of their misconceptions. Even if we could plug all the gaps in teens' knowledge, hormones may still sometimes override reason, leading teens to do things that they *know* are wrong for them (just as sometimes happens to their elders). Educators' preconceptions (and ego defenses) may keep them from absorbing inconvenient facts about teens' predicaments (e.g., they may not want to face just how severely endemic violence and weak job prospects can reduce teens' time horizons). Moreover, if educators did understand these realities, they might still be powerless to affect them (given the limits to what schools can do).

Such complexity is the everyday fare of those concerned with teens' welfare, whether designing, applying, or evaluating interventions. We offer here an approach to thinking about the complexity that has guided our own research in adolescent risk taking, some of which will be used as illustration. The approach combines the substantive knowledge of psychology with the formal modeling perspective of risk analysis (Morgan & Henrion, 1990). We believe that it offers some promise for integrating existing research and focusing future efforts. The approach can be used with varying degrees of intensity, from producing quantitative assessments of the effectiveness of interventions to providing a common qualitative language for describing diverse theories and interventions.

A comprehensive risk analysis for adolescent vulnerability would begin by asking which factors create a risk and what can be done about them. As in the example just described, those interventions might attempt to change either the situations posing a risk or teens' responses to them. The analysis would then identify the qualitative relationships among those factors, followed by quantitative estimates of these dependencies. Where possible, those estimates are taken directly from the scientific literature. When fully substantiated numbers are lacking, expert judgment is substituted—elicited with procedures that clarify how much faith to place in the estimates (and in the conclusions of analyses that rely on them). A frank assessment of the uncertainty surrounding model parameters also allows one to determine where future research could do the most to improve the accuracy of risk estimates. The next section illustrates this general approach with a specific example.

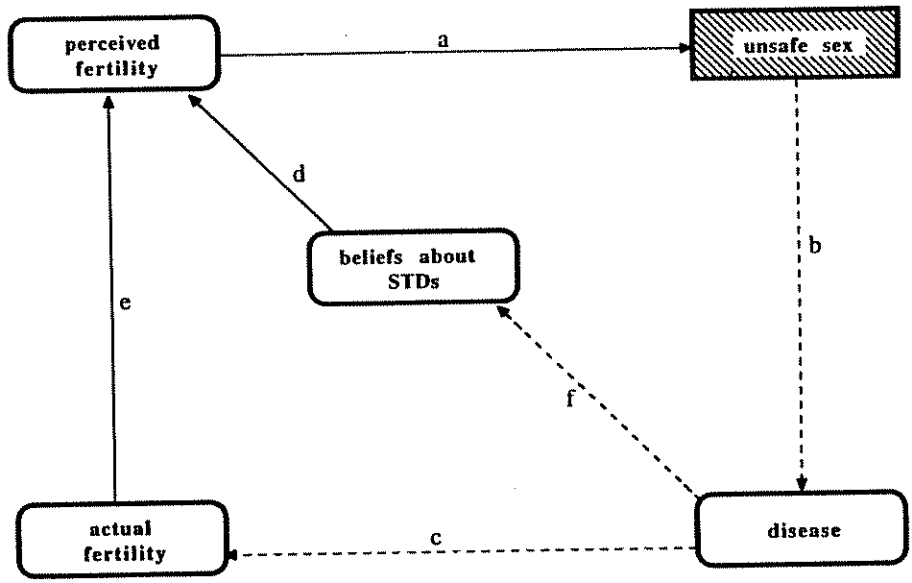

Figure 1. Influence diagram depicting a simplified model of the relationship between fertility and sexually transmitted diseases. The value of the variable at the point of an arrow depends on the value of the variable at its tail.

A Language for Sources of Vulnerability

Figure 1 shows a simple (and incomplete) risk model for teen sexuality. It could be interpreted as any sort of directed graph, describing any sort of loosely defined relationships. However, it also follows the rules of a particular formalism called the *influence diagram* (Burns & Clemen, 1993; Howard, 1989). In the model, the unshaded nodes represent chance variables, and the shaded nodes represent actions. An arrow means that the value of a node depends on the value of the preceding node. Thus, for example, believing that one is infertile should influence the probability of unsafe sex (other things being equal, why use protection if one cannot get pregnant?) (link *a*). That, in turn, should affect the probability of a disease (like chlamydia) (link *b*). Having the disease changes the probability of some health states, including actual fertility (link *c*). Changes in perceived fertility (whether justified or not) could affect subsequent sexuality, making this a recursive model. The solid lines in the figure represent the factors affecting an initial decision; the dashed lines represent the consequences of that decision, setting the stage for the next round of decisions. The contingencies in the model might be affected by interventions such as providing better information about the risks of chlamydia or better treatment for it.[1]

In the model presented in Figure 1, the conditional probabilities in link *a* might be estimated through structured interviews with teens or professionals who have occasion to discuss these issues with teens (e.g., family planning nurses). The conditional probabilities for links *b* and *c* could be determined by clinical studies of disease transmissibility and development, respectively. Psychological studies can assess how perception of personal fertility is related to beliefs about STDs and actual fertility links (links *d* and *e*, respectively), as well as what people learn from disease experiences (link *f*). In their most general form, these dependencies are bivariate conditional distributions, capturing, for example, probabilities of unsafe sex among a population of youths, as a function of their fertility beliefs. More restrictively (and more realistically, given data requirements), one might simply show the sexual activity typical for teens with a given belief.

The overall health risk from chlamydia for a particular situation would be estimated by setting the appropriate values for its relevant precursors. For example, one might consider the risk of getting chlamydia for a group of young women convinced that they are infertile. If they are also relatively unconcerned about STDs, then they might have a fairly high rate of unsafe sex. Cascading these risks through the model would lead to some relatively high rate of disease and consequent fertility problems. If nothing were known about these beliefs, then the model could also be truncated and computed for teens with a particular rate of unsafe sex (whatever its sources).

Evaluating Interventions Designed to Reduce Vulnerability

In an influence diagram, the impact of an intervention is modeled by changing those parameter values that it is ex-

[1] As an example of a noncausal dependency, one might include social class as a predictor of actual fertility, where it is not the direct source of influence, but a surrogate for causal factors such as nutrition, education, and access to health care

pected to affect (Kaplan & Brandeau, 1994). For example, an informational campaign might increase young women's estimates of their own fertility (perhaps by helping them to interpret the implications of not getting pregnant from their first few sexual encounters). Running the model with those revised values would show the health impact of such a program. If costs were known, too, along with the dollar equivalent of the health benefits, then one could compute the program's net economic impact. One could perform comparable calculations for programs aimed at improving teens' understanding of disease signs (so that they get to treatment more quickly) or for programs aimed at improving teens' access to condoms (so that there is more protected sex at any perceived fertility level).

Because there is uncertainty in both the individual estimates and the conditional dependencies, there will also be uncertainty in the estimates of health effects (and the impacts of programs on them). Scientific research might be able to reduce these uncertainties, as characterized in the model. For example, one might sharpen estimates of teens' beliefs in their fertility or of the relationships between those beliefs and sexual behavior. Those improved estimates should make the results of interventions more predictable and might even affect the probabilities enough to change the choice of intervention. If that change actually saved money (or increased benefits), then the research would have a demonstrable economic benefit (in addition to any theoretical contribution).

Why Bother with a Framework?

A comprehensive model provides a framework for integrating diverse studies related to a single domain. If the relationships can be quantified, then the model allows one to predict overall risk, to assess the effects (and even cost-effectiveness) of alternative interventions, to identify practically important research projects, and even to evaluate the economic impact of basic research. Proposals for such analyses are sometimes raised, often as attempts to defend the budget for a science by showing its coherence and practicality (e.g., Cozzens, 1995; National Research Council, 1984, 1995a, 1995b). They are seldom implemented, however, even as complements to the intensive, informal expert discussions that typically determine research agendas and select interventions (e.g., National Institute of Mental Health Council Task Force, 1996; Office of Science and Technology Policy, 1991).

Although often stimulating and productive, such group deliberations may not show how conclusions were reached (beyond reflecting the group's considered opinion), nor even establish a common nomenclature for integration and comparison. We offer here a top-down approach for examining the full suite of processes producing and controlling risks, thereby providing a common language for describing diverse approaches. Our hope is to advance science and practice by explicitly setting existing work in a broader context (e.g., Botvin et al., 1995; Winnett, 1995), perhaps speeding their integration and the identification of gaps. We explore the possibilities of this approach with one major set of risks facing teens: those posed by infectious disease, with a particular focus on the specific vulnerabilities created by sexual activity—and the options for their control.[2]

Arguably, those who must cope with risks (e.g., teens) need at least as comprehensive a view as those who study them. They cannot afford to focus on a narrow slice of life, nor to insulate themselves from the consequences of misunderstanding any part of a risky process. For example, teens who think of an STD when contemplating a sexual liaison may want to consider its incidence (whether it is "going around"), its detectability (in a partner), its treatability, its (physical and psychological) painfulness, its impact on future liaisons, their personal susceptibility (given past experiences), and so on. Fundamental mistakes in any area can undermine a wealth of knowledge in others. Teens also need to know about the social and psychological consequences of risk behaviors. Some of the breakthroughs in social skills training programs (Botvin et al., 1995) seem to come from addressing such misconceptions, such as how widely shared and respected various behaviors are. Moreover, the programs do so in ways that can change the social reality within which decisions are made—as can social marketing programs (Winnett, 1995).

An influence diagram can offer a comprehensive model for conceptualizing the processes creating and controlling risks. It can be used in several ways. One is as a task analysis, characterizing the places from which vulnerability could spring. The second is as a device for integrating the diverse literatures studying these complex processes. The third is as a template for evaluating the beliefs of teens and their caretakers, and the potential effectiveness of possible interventions. The next section presents a general risk model for infectious disease. This proposal does not claim to prescribe a universal theory of disease-related behavior, nor does it lay out our own millenial plan for data collection, in whose service we hope to enlist the research community. Rather, it attempts to lay out a framework that will help to coordinate the efforts of scientists pursuing their own predilections. We hope that it will help to reveal the mutual implications of existing efforts and to improve the design of future ones.

Models of Vulnerability

The spread and control of disease is often very complicated. No one scientific study can hope to understand any disease in its entirety. Nor can any one intervention hope to address all

[2] Fischhoff and Beyth-Marom (1983) offer a somewhat analogous attempt to provide such a framework for the diverse work on judgmental biases. Their framework is the formal one offered by the rules of Bayesian inference, whereas the present framework is the substantive one dictated by the realities of disease processes (but expressed in a formal language that is compatible with Bayesian inference).

elements of a disease's spread and treatment. As a result, scientists and practitioners typically confine themselves to one aspect of the disease process—reflecting where they believe the action to be, within the constraints of where they are qualified (or allowed) to act. Although a natural response to complexity, this division of labor poses a challenge to the accumulation of knowledge. It can be hard to know how the pieces fit together, and what is their relative importance.

Figure 2 offers a general model for infectious diseases, showing the relationships among the volitional acts and natural events that determine the risk of a disease spreading, and then causing adverse health consequences. Like other influence diagrams, this one conceptualizes the relations in a way that allows the risks to be calculated, once quantitative estimates of model parameters are provided. Even when those estimates are unavailable, creating a calculable model forces one to work out the relations among the constituent processes. The relations depicted in a model must pass through both a *logical* and an *empirical* screen. The former determines which factors could affect which other ones; the latter asks which of these possible relations are plausible—based on specific studies or general theories. Ideally, a model would also pass a practicality screen, identifying relationships that could be manipulated to reduce vulnerabilities.

Figure 2 summarizes these processes, at a high level of abstraction. It depicts individuals as making decisions leading to actions that might expose them to a disease from others whose health has already been compromised. Those decisions can be affected by their own health, others' health, and other mitigating factors (lumped together in a single node). The probability of disease transmission depends on their own health state. If transmission occurs, then it may change the individual's own health state, possibly in a way that is subject to treatment. Exposed individuals may, in turn, become the source of disease for others. People whose health has been changed may make different future decisions, possibly affecting subsequent exposures.

Figure 3 elaborates this basic model, for a broad set of infectious-disease processes. Figure 4 takes that model one step further, focusing on the issues most relevant to sexually transmitted diseases, one of the greatest threats to teens' well-being (Dryfoos, 1990). This embedding (of Figure 4 in Figure 3) also serves as a reminder that teens must contend with STDs as part of dealing with other infectious diseases, drawing on some of the same beliefs and experiences. Despite their complexity, both figures have also passed both screening processes. That is, we have worked through the logical relations that might exist in principle, and reviewed the literature for the empirical relations that seem to exist in reality. As a result, the figures are less complicated than they might otherwise have been. Moving from a more general domain (Figure 3) to a more specific one (Figure 4) allows one to elaborate nodes in ways that are particularly pertinent.

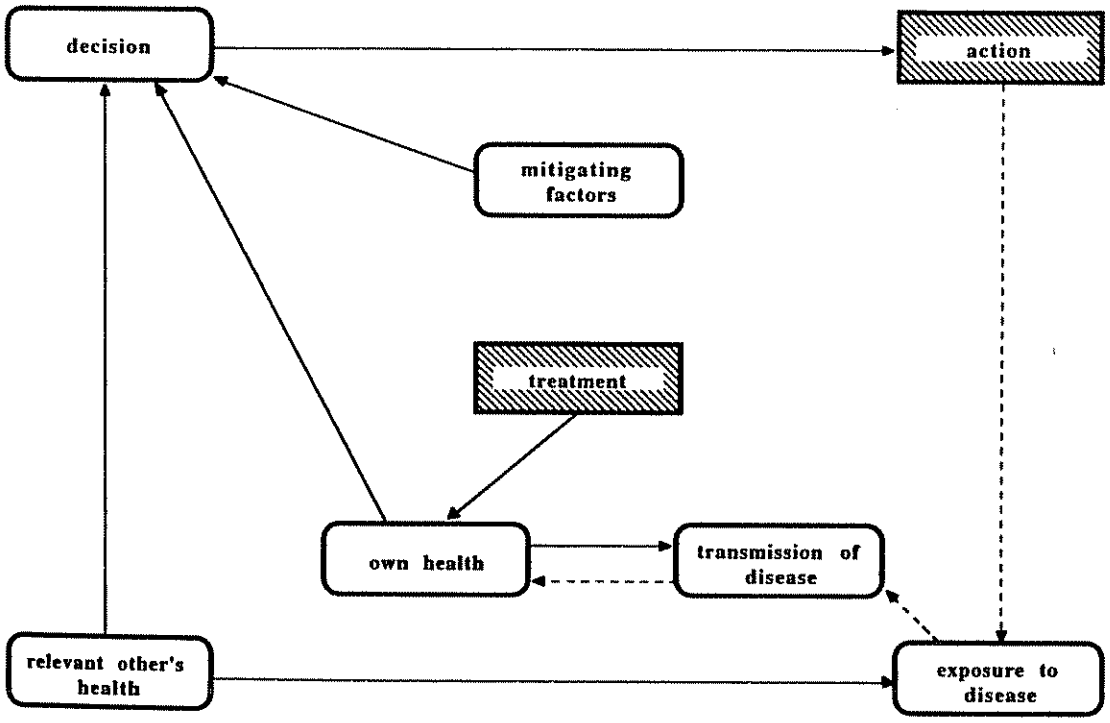

Figure 2. A general model of infectious-disease transmission, showing the relationships among decisions, behaviors, and disease processes.

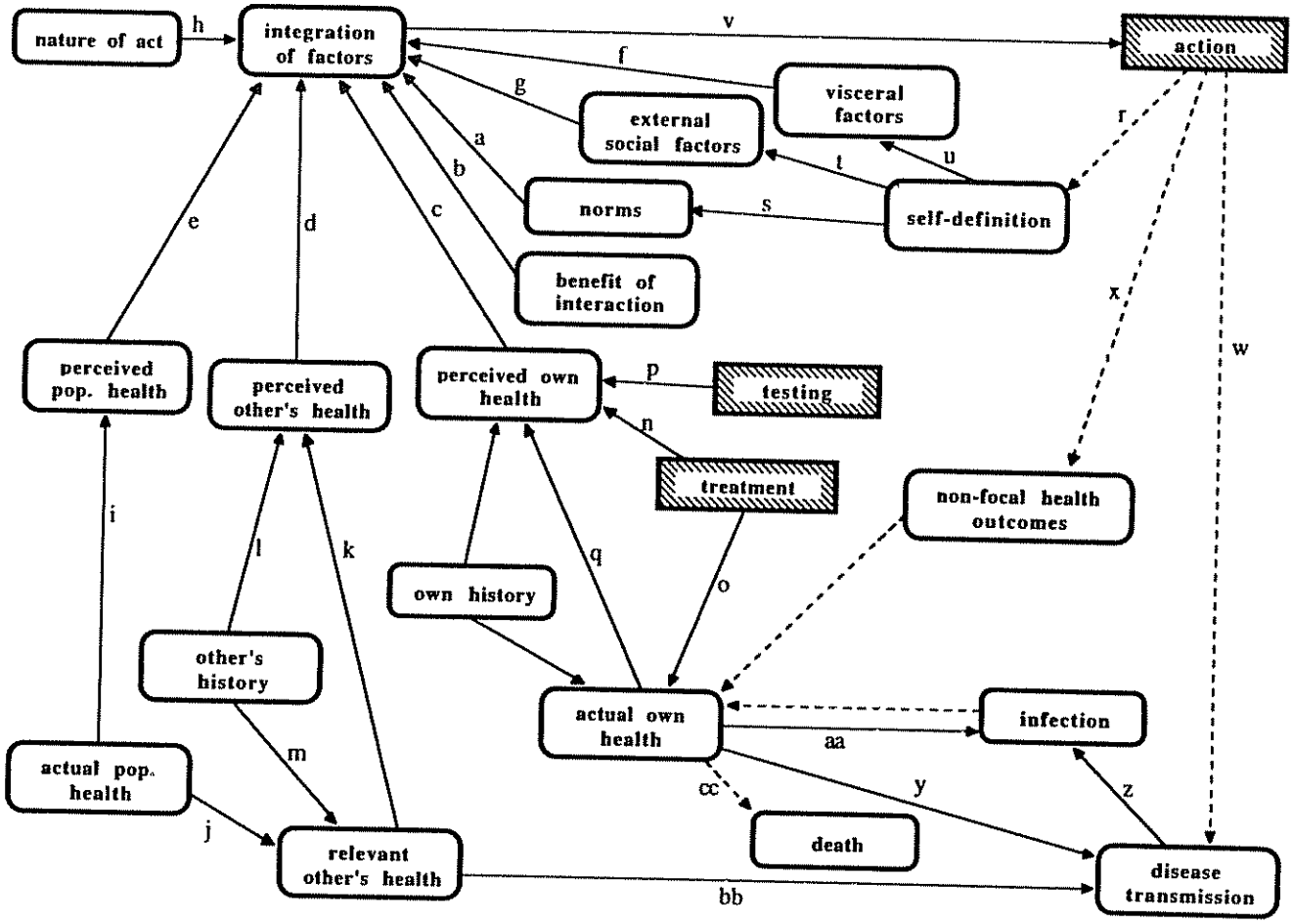

Figure 3. A template for creating influence diagrams for specific infectious diseases. This model includes many of the decision-making factors that are available to an individual, as well as the mitigating factors that might influence the individual's decision or information use. It also includes the consequences of action, with effects on the individual's health and nonhealth status

Infectious Disease Model

Choice of Action

People are exposed to infectious diseases as a result of their own actions (Figure 3). Those exposures may be deliberate (e.g., caring for a sick child) or unwitting (e.g., flying next to someone in the incubation stage of chickenpox). The choice of that action could be influenced by perceptions, regarding the norms seen to govern the situation (link *a*), the benefits of the interaction (e.g., being with one's child in a time of need) (link *b*), one's own perceived health (an indicator of vulnerability to disease) (link *c*), the other person's perceived health (and contagiousness) (link *d*), and perceived population health (in the sense of "what is going around") (link *e*). All these considerations are available for incorporation in the choice process, represented as "integration of factors." The exercise of any decision rule requires freedom of choice, which may be affected by both internal and external forces. The former are represented as "visceral factors" (link *f*), including influences such as craving, intoxication, and anger, which override cognition (so that people may know that what they are doing is too risky, but be unwilling to stop it) (Loewenstein, 1996). The latter are represented by "external social factors" (link *g*), including physical constraints, such as coercion, forcing people to do things that they would rather not, and socioeconomic factors, restricting the set of available options.

The integration process could involve some sort of cost–benefit "calculus," weighing the perceived good and bad consequences in a way that balanced the two. Or, it could be a noncompensatory rule, in which one consideration could trump all others (e.g., not violating a social norm, however great the other costs or benefits). Being ruled by passion would qualify as such a rule, as would submitting to an armed sexual assault. The possibility that different rules are systematically followed in different domains is represented by "nature of the act" (link *h*). Like the other nodes, it represents a variable whose value can affect that of the

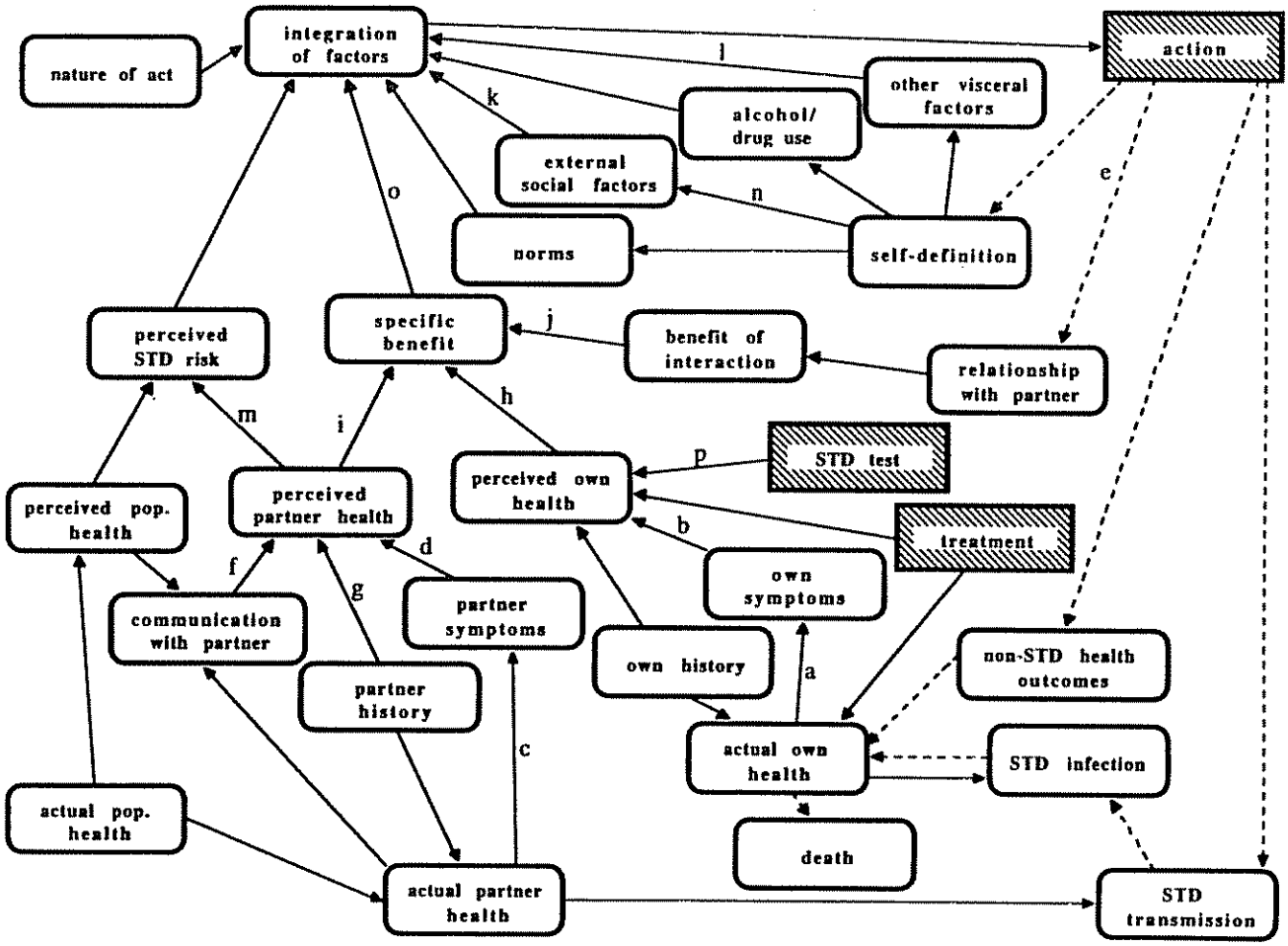

Figure 4. A more complete influence diagram of the risks involved with sexually transmitted diseases. Factors that seem most important for predicting the risk of sexually transmitted diseases and sex-related decision making are expanded from the general model of Figure 3.

node to which it is attached. Thus, a norm-driven choice might be more likely in some domains than others, as might a calculated decision (e.g., Payne, 1982). Similarly, the perceived probability that diseases are going around (and might be spread by the act) should lower the probability of the act, assuming that some balancing is going on, and so on.[3] Some variant of this process underlies most of the decision-making models used in health psychology, several of which are interpreted in these terms in the next section.

[3] The terror felt in a time of plague might turn this variable into a visceral response. Accommodating that possibility would mean drawing a line between "perceived population health" and "visceral factors." As this is a link that would seldom be activated, however, it is omitted in the interest of simplicity. A sufficiently high probability could dominate the integration process directly, achieving the same effect as working through "visceral factors," although somewhat misrepresenting the causal mechanisms.

Precursors to Choice

Each factor directly influencing choice has the value of the associated variable set by earlier events. Figure 3 offers a set of plausible precursors to choice, drawn from existing research results and common sense. Thus, actual population health can influence perceived population health directly (link *i*)—although without becoming synonymous, given the hidden nature of much health and people's (cognitive and motivational) tendencies to misinterpret what they can observe. It can also influence the perception of others' health indirectly, by affecting the others' actual health (link *j*)—the visible elements of which (link *k*) are combined with knowledge of the others' history (link *l*) to produce a judgment of other's health (e.g., he looks fine now, but he used to sleep around). That health state is influenced by the other's history (of treatment, actions, etc.) (link *m*).

Getting treatment can affect perceptions of one's own

health (link *n*) and that health itself (link *o*), somewhat independently. (Like other choices, "treatment" is represented by a shaded box).[4] The act of testing can also influence those perceptions (link *p*). The node for "nonfocal health outcomes" is meant to capture health outcomes that are not specific to the disease being modeled (e.g., catching the flu from a sexual partner). Perceived own health should be somewhat related to one's actual health (link *q*).

Finally, "self-definition" represents the psychological factors, short- or long-term, that are relevant to health decisions. Acting in a way that exposes oneself to a disease (or avoids exposure) can alter one's idea of oneself (link *r*), both personally and socially. For example, kissing a partner when he or she obviously has a cold could reinforce one's perception of being devoted. This, in turn, could affect the norms of the relationship (link *s*); such devoted behavior could become expected in the future, or optional if one has passed a test of fidelity. Likewise, refusing to shake hands with a stranger in a business setting could increase one's self-efficacy in these situations, helping one resist social pressure (link *t*) to shake hands in future business dealings and control any visceral feelings that are aroused (link *u*).

Consequences of Action

After the factors are integrated, they lead to some action (link *v*). The choice/integration act is distinguished from the action because things do not always go as planned. People may not be able to carry out their intentions as a result of unexpected disruptive forces, failure of the will, missteps in execution, and so on. That action can allow for transmission of the disease in question (link *w*), as well as affect nonfocal health outcomes (link *x*). Whether the former happens may depend on elements of the individual's own health state (e.g., do they have sores facilitating transmission) (link *y*), as might the chance of disease transmission leading to infection (link *z*), which is also affected by one's own health state (e.g., does he or she have a compromised immune system?) (link *aa*). Transmission depends, of course, on the other's actual health state (how catchy a form of the focal disease—and its potentiators—does that person have?) (link *bb*).[5]

Barring death (link *cc*), the outcomes of each action set the initial conditions for the next possible exposure-related decision. Often, these conditions will be virtually identical from round to round. If a disease is not going around, the chances of having it are independent of one's actions. Those actions may not change anything else in one's life, and so on. Alternatively, conditions can change as the result of one's own actions (if they affect self-definition, focal or nonfocal health outcomes). Or, the world can change, most notably through changes in how healthy the rest of the population is and how the "other person" interacts with it. Thus, the risks of sharing food with one's children can change if flu starts going around or if they start going to day care.

Generality

While developing Figure 3, we applied it to a variety of infectious diseases, in order to see whether the general model could accommodate their special properties. One of these cases was the ebola virus. There, the critical "others" include sick relatives and patients; the "norms" include the obligation, in some cultures, to make physical contact with deceased relatives; "actual population health" quickly affects "perceived population health" which, in turn, affects choices. The panic created by an epidemic might become a "visceral factor," leading to the shunning of possible victims, even when reason dictates that there is no risk. At the other extreme, the figure can also accommodate common colds. There, treatment can affect symptoms, but not the underlying health state (so that link *o* would vanish); perceived other's health is an imperfect guide, in presymptomatic (or heavily treated) states; norms may create pressure for exposures known to be ill advised (e.g., shaking hands with a job candidate who has caught a cold on the plane going to job talks).

As complex as Figure 3 is, it does not do full justice to many of the nodes. For example, "self-definition," has been described as having several dimensions. Investigators interested in these distinctions could elaborate this aspect of the general model, with separate nodes for each variable. They might collapse other variables, choosing to ignore those issues. Conversely, investigators interested in broader disease processes might seek the single best measure of self-definition for their predictive purposes, ignoring its nuances.

Like any summary of scientific results, the relationships proposed here require the interpretation of existing studies. One of the following sections describes how alternative versions of this model could be used to characterize the similarities and differences among competing theories.

Sexually Transmitted (Infectious) Diseases

Figure 4 adapts the influence diagram of Figure 3 to the special case of sexually transmitted diseases (STDs). That adaptation involves the following steps:

1. The most common change is sharpening the name in a node to refer to STDs (e.g., from disease transmission to STD transmission, from other's history to partner history).

[4] If this model focused on treatment choices, an obvious precursor would be "perceived own health." Adding an arrow between these two nodes in Figure 3 (which focuses on decisions that could create exposures that might eventually require treatment) would add a recursive loop, rendering the model incalculable (because A would cause B, which simultaneously causes A . . . .) Feedback is possible within a model; however, the events need to be sequenced (e.g., so that B's influence on A occurs after A's influence on B). Treatment decisions could be the subject of their own influence diagram, some of whose variables are in this model, whereas others are specific to treatment (e.g., medical coverage, apprehensions over sins of omission and commission).

[5] In the interests of space, several links are left unexplained, as they parallel ones that are explained.

2. In a few cases, an intermediate node is added within a link in order to highlight mechanisms specific to STDs. For example, own health and partner health are shown as influencing perceived health through visible symptoms (links *a* and *b*, links *c* and *d*).

3. Because substance use is particularly important in decisions about sex, the visceral-factors node is divided into "alcohol/drug use" and "other visceral factors." In a more detailed influence diagram, alcohol/drug use, too, could be treated as a complex decision, with its own precursors and determinants; however, it is just a precursor variable in this figure, focused on decisions about sexual acts.

4. Because sexual relations are often parts of continuing personal relations, an additional feedback loop is added, regarding how the chosen action (i.e., the kind of sex, if any) affects that relationship (link *e*). A similar loop could be added to the general figure (Figure 3) for other diseases where it might be significant (i.e., where things looked substantially different the next time that a disease-related decision presented itself).

5. The continuing nature of these relations also prompted adding a link for "communication with partner" as a way to assess partner's health (link *f*)—in addition to the observation of partner symptoms (link *d*) and the evaluation of partner history (link *g*) (e.g., previous partners).

6. The physical and psychological pleasure sought in sexual relations often depends on the perceived physical health of both partners. Many people enjoy the act less when physically ill, both in terms of their own hedonic response and their concern for communicating a disease to their partner. Similarly, they enjoy it less when their partner is the apparently sick one. As a result, perceived own (link *h*) and perceived partner's health (link *i*) combine with the general "benefit of interaction" (link *j*) to produce its "specific benefit."

These changes reflect the logic of creating any influence diagram. Links are added or subtracted in order to capture relationships creating and controlling a risky process. A link is retained as long as there is (empirical or intuitive) reason to believe that the value of the variable at the arrow's head depends on the value of the variable at its tail. Other things being equal, preference is given to variables that can be observed and might be manipulated in risk-reducing interventions. The next section considers whether Figures 3 and 4 are, in fact, defensible models for these risky processes.

How Do We Know That This Is the Right Model?

As mentioned, the adequacy of a model can be judged on logical, empirical, and practical grounds. The first of these criteria asks whether the structure of the model matches that of the processes that it is meant to capture. The second asks whether it corresponds to scientifically credible theories and established empirical facts. The third asks whether it can clarify the status of existing interventions and direct the design of future ones. The following sections subject these models of vulnerability to each test in turn. We then describe a program of our own work, guided by this modeling perspective.

Does It Pass the Logical Screen?

Any formal language has a syntax that applications must follow. Indeed, part of the value of modeling is submitting to the discipline of expressing oneself in such a language. In an influence diagram, that means (a) specifying the variable appearing at each node; (b) assessing whether there is a possible relationship between the variables in each pair of nodes, in order to know which should be connected; and (c) ensuring that the feedback processes make sense. This value can be obtained even if the model is not taken to the next stage, assessing the conditional probability distributions associated with each link. Even where the data requirements for producing firm probability assessments seem preposterous, it can still be illuminating to force oneself to consider what they might be. We have done so with successive iterations of these models, as a path to the versions presented here.

Any general model should be readily adapted to specific instances of the process that it is meant to capture. For a general model of infectious disease, the first test is how well it fits specific diseases. The comparison between Figures 3 and 4 is one measure of our success in this regard. As mentioned, the adaptation to STDs involved elaborating several links that seemed particularly important to decisions regarding sex. A natural next step would be adapting the STD model to specific STDs. We believe that these models would follow from the general STD model in straightforward ways. The variables at each node would sometimes change, in order to fit the specifics of each disease. For example, infertility can be affected by some diseases and not others, or death would sometimes disappear as a consequence. In other cases, the variables stay the same, but the contingencies change. For example, treatment has different effects on different diseases—and on people's perceptions of them; there may also be different degrees of variability in the treatment (as a function of the consistency of medical care or patient responsiveness).

Within the domain of STDs, we checked that there was a place for sexual assaults (external social factors, link *k*), for running hormones (other visceral factors, link *l*), for training in condom use (increased benefit, link *j*; reduced relevance of partner health, link *m*), for one-time and repeated liaisons

(increased communication with partner, link *f*; better interpretation of partner history, link *g*), and so on. Individual differences can be accommodated in the specification of dependencies. For example, impulsivity (should such a tendency exist) would change the impact of "other visceral factors" on the decision-making process (link *l*); deep religious commitment would change self-definition, hence sensitivity to external social factors (link *n*); preference for novelty (if it exists) would change the benefit from more adventurous sexual acts and the weight they carry in the overall integration of factors (link *o*); and so on.

The structure of the model implies that such changes affect only the nodes "downstream" from them, so that everything does not have to be reset with every such change. Indeed, a goal of the relevant social sciences is to identify the factors whose effects vary by context. For example, the tendency known as the "base-rate fallacy" would lead one to predict insensitivity to actual population health, unless there is an awareness of "something going around." Similarly, insensitivity to test validity would suggest that diagnostic reports are interpreted literally (link *p*), across situations in which they vary widely in reliability (Tversky & Kahneman, 1974). Increases in feelings of self-efficacy (an element of self-definition) might reduce the impact of external social factors (link *n*) in cases where such factors increase exposure to diseases, as well as other risks (Bandura, 1982). At the very least, the values observed in one context provide a point of departure for conceptualizing the risks in others.

Does It Pass the Empirical Screen?

Validity of Assertions in Links

The fact that every node is not connected to every other node reflects a belief that not everything affects everything else (or at least not directly). Thus, the model represents a collection of empirical statements. Often, these are quite modest claims. For example, people's choices of social interactions clearly can be influenced by alcohol, anger, norms, perceived benefits, and so on. In such cases, the research challenge is to specify when and how these potential influences come into effect. For example, where do social norms become an issue (beyond their internalization into an individual's own evaluation of possible actions), how accurately are they perceived, and what are the sources of misperceptions? Or, when do people begin to think about partners as potential disease vectors, what cues do they look for, and how much confidence do they place in that extraction process?

Each such suite of questions could constitute a full-time research project. Pursuing those questions within the context of an integrative model means having a standard specification of what is being held constant—and what boundary conditions to examine when establishing the generalizability of results. Such a model provides a complementary perspective to the common approach of working outward from existing results to identify boundary conditions. It can also make results more accessible to investigators in neighboring areas, by expressing them in common terms. Finally, it might highlight neglected areas (e.g., how perceived own health affects the perceived benefit of sexual interactions; how people interpret the results of diagnostic tests).

Adding a link makes a strong statement only for those who believe that a factor is irrelevant (over some range of disease situations). For example, some researchers have claimed that people ignore population base rates, relying entirely on perceptions regarding individual cases (Nisbett & Ross, 1980). If so, then perceived population health would have no direct effect on STD risk perceptions, being swamped by perceived partner health. It might, however, have indirect effects, say, by influencing a partner's health state and willingness to talk about such issues.[6] As another example, the model lacks a link between perceived own health and perceived STD risk (from partner). Conceivably, people see less risk in others once they themselves are sick already from a particular disease. Our belief in omitting this link is that it would have little additional predictive power, after factoring in the effect of being sick on the net benefit from intimate relations with others (reduced both by fear of spreading the disease and by reduced ability to enjoy the act). People may also believe that additional exposure to a sick partner may aggravate his or her condition, so that the increment in perceived risk is the same for healthy and sick individuals.

Thus, any model presents empirical claims that could be tested at the level of individual links or subdomains. For example, one could ask people what they believe about the incremental risks of exposure, as a function of their (actual or hypothetical) health state. Or, one could measure the variables at each node in a part of the model and perform a structural equation analysis of the relations within it (Burns & Clemen, 1993), in order to see which are direct, indirect, and negligible. As elsewhere, considering the overall model circumscribes the boundary conditions for these studies (e.g., which disease, what testing opportunities, what symptom detectability).

Relation to Psychological Theories

Obviously, these are very complicated processes. In order to reduce them to manageable size, various investigators have developed models for predicting behavior on the basis of a smallish set of summary variables.[7] Perhaps the most venerable such theory is the health belief model (Becker, 1974). It holds that behavior is a linear function of the

[6] Note that, in this case as all others, the influence need not be causal. Rather, there just needs to be a dependency between linked variables. Thus, it is not the prevalence of a disease that causes someone to get sick; however, it is associated with a higher probability of that happening.

[7] We only do the mapping here in general terms, insofar as a full mapping would require too much attention to the details of variable specifications in particular versions of each model.

perceived threat of a negative outcome and the costs and benefits of the focal behavior. The degree of perceived threat depends on the perceived severity and likelihood of the possible consequences of disease transmission. Those perceptions depend on the salience of various cues. Members of this family of models map readily onto Figures 3 and 4. Each version has, in effect, an "integration-of-factors" node summarizing some expression of the perceived risks and benefits of an act. Those perceptions should depend on people's beliefs about the infectious-disease process. For example, if they believe that death is possible, whereas treatment is not, then their attention should be focused on those cues (perhaps effectively, perhaps not). Their beliefs about treatment, observable symptomatology, and partner communication should affect perceptions of partner health.

For health belief models, the integration of factors involves a linear rule aggregating these judgments. In other research, simple linear models have been found to be powerful predictors of even complex balancing processes (where being good in one respect can compensate for being bad in another) (Dawes & Corrigan, 1974; Dawes, Faust, & Meehl, 1989). As a result, such models can capture input–output relations without capturing the cognitive processes involved or even the variables that directly occupy people (insofar as surrogates can provide similar predictive ability). Indeed, the proliferation of linear models reflects, in part, the difficulty of discriminating among them. Each will work about equally well as long as it has representatives of the same classes of variables. Each will work fairly well as long as those classes include the major ones that influence behavior, and these factors can balance out one another (as demanded by the additive structure of linear rules).

One important class of elaborations on the health belief model is the succession of models offered by the Theory of Reasoned Action and Theory of Planned Behavior (Ajzen, 1985; Terry, Gallois, & McCamish, 1993). In terms of the influence diagram, these theories provide explicit roles for "norms," reflecting what people believe is the appropriate thing to do (perhaps broken down by specific reference classes, such as parents or peers), and "external social forces," reflecting more directly applied pressure. The model distinguishes intentions from the actions following from them, with various visceral factors determining whether people are in sufficient control of their affairs to act on their intentions. The diagrams capture this distinction in the separation between choice of action and action. The imperfections in this connection, however, are represented as reflecting some set of unspecified factors (e.g., failures of execution, interruptions, changing circumstances), whereas the social and visceral factors are represented as influencing the decision-making process (e.g., allowing for drunk individuals to weight factors differently). The diagrams could be brought into closer correspondence with this class of theories by moving those arrows from the decision-making node to the action one, so that they constitute additional influences there. How these influences work is an empirical question, albeit a nontrivial one (Boyd, Howard, & Zucker, 1995; Millstein, Petersen & Nightingale, 1993).

Another class of theories, sparked by Bandura's (e.g., 1982) concept of self-efficacy, focuses on the control processes at the tops of the Figures. These accounts hold that people try to act on their environment to the extent that they feel that they can. Four major determinants of self-efficacy are (a) previous experiences of success and failure, (b) vicarious experiences, (c) feedback from others about one's abilities, and (d) physiological states. In terms of the diagram, feelings of self-efficacy are an element (or perhaps an operationalization) of self-definition; they help to determine the extent to which people allow viseral and social factors to govern their behavior. Those feelings depend, in part, on the cumulative impact of the feedback depicted in the diagram, from successive rounds of action and consequences. They depend, too, on people's mental models of the overall process: How controllable it seems to be and how well they seem to have mastered its details. A complication in fitting the theory to the model is that general feelings of self-efficacy seem to set up predispositions to control situations, whereas transient feelings of self-efficacy are affected by the social and visceral pressures evoked by specific situations—hence whether people actually act on their beliefs.[8]

Social Action Theory (Ewart, 1991) predicts that people will make more rational decisions to the extent that they not only have justified feelings of self efficacy, but also have the cognitive abilities to (a) generate decision options worth evaluating, (b) identify the goals that should be the focus of their personal striving, and (c) predict the effects of different actions on their goals. The first two of these conditions set the terms of the model for different individuals (determining the acts being considered and specifying "risk" and "benefit," as well as the weight associated with different factors in the integration process). The third condition reflects the accuracy of their mental models for the process as a whole. The Transtheoretic (or Stages-of-Change) Model focuses on how additional elements of the general model are successively activated by increasing involvement with a decision-making process (Prochaska & DiClemente, 1983). Such mappings can clarify how these theories might be integrated and discriminated, when they are studying the same topics under different labels and when they elaborate one another's precursors and consequents.

Does It Pass the Practical Screen?

As mentioned, the most ambitious practical application of an influence diagram would be to predict the effect of a proposed intervention, by translating it into the terms of the

[8] Thus, in a model fully representing this theory, there would be an arrow from visceral factors to self-efficacy (as an expression of self definition) and none to integration of factors.

model and then using the best-available link estimates to predict its effect. Those estimates could come from published studies (e.g., meta-analyses of effect size) or from expert elicitations, asking for subjective assessments of the probability distributions. Although uncommon in the social sciences, such formal elicitations are relatively common in analyzing complex natural processes (e.g., Morgan & Keith, 1995). This exercise in itself can sharpen thought processes and reveal the degree of agreement within the community of experts—itself a valuable input to those hoping to base interventions on experts' recommendations (Funtowicz & Ravetz, 1990). It might also improve communication with experts, by generating very specific questions that one would like answered—in a probabilistic framework that allows experts to surround their best guesses with as much uncertainty as they deem necessary.

For example, Bob Cook, a member of our research group, has proposed increasing adolescents' rate of STD testing by using less invasive tests. Rather than undergoing an uncomfortable gynecological exam or urethral swab, teens would provide a urine sample or use a self-inserted vaginal swab. These tests are as reliable as the more invasive tests, but cost twice as much. A field trial will test the impact on testing rates of making the noninvasive test available. If easier tests mean more testing, then the model provides a way to evaluate the impact on disease processes—a step toward assessing the net economic cost or benefit of such testing. If one assumes that people with STDs respond similarly, whether the bad news comes from an invasive or a noninvasive test, then the only change in the model would be in the rate of people undergoing testing. Those who receive positive test results (i.e., evidence of disease) should change their perceived own health status. That might change the net benefit of the sexual interaction, from diminished pleasure and increased worry over transmission to partners. That reduction might be enough to change some choices regarding sexual acts. That, in turn, would reduce the number of acts, the rate of STD transmission, and the incidence of subsequent infections. Those who test positive for a treatable STD might also be more likely to seek treatment; when the STD is cured, transmission rates would be lower for future partners. Isolating this section of the model provides a "mini-model" of the factors critical to estimating the health effects of this intervention. One could then consult the relevant segments of the research literature (or research community) for estimates for individual links, and collect those that are missing (as Cook and his colleagues will be doing). Other segments of the model would be isolated for interventions focused on, say, improving communication among partners, making condom use more acceptable socially, or encouraging drink-free parties.

The impacts of some interventions would be less direct than some of those from Cook's testing proposal. For example, consider an improved treatment for an STD (e.g., with greater efficacy at reduced expense and inconvenience). Those receiving that treatment would change their own health, symptoms, and perceived health—in ways that could be estimated from a clinical trial and incorporated in the model. If healthy people perceive their own health accurately, then the benefit of sexual interactions could increase. Other things being equal, that should lead to more sex, the disease consequences of which depend on the actual health of their partners and the transmissibility of the STD. Knowing that a cure is readily available might diminish the role of perceived risk—meaning that there would be more transmission, unless, of course, sex with a sick partner was still aversive. (Where treatment is readily available, a partner who remains sick might be viewed with particular disdain.) In order to project the impact of an intervention fully, one would need to identify and estimate all such changes. In order to evaluate an intervention, one would want to measure these intermediate determinants of its focal effects.

Finally, a model can help to characterize existing interventions. For example, many programs attempt to implement the theoretical approaches described earlier. Their faithfulness to the underlying theory can be clarified by mapping their activities into the model, noting the relative attention devoted to each. For example, a full program for enhancing teens' feelings of self-efficacy would have components helping them to manage social norms, external social factors, and visceral factors. If not, then it does not provide a fair test of self-efficacy theory. Where a program seems to miss parts of the process, such mapping can help one identify (and adopt) complementary pieces from other programs.

In a current study, we have used this perspective to characterize the material presented in several widely available communications, intended to protect adolescents from the risks of human immunodeficiency virus (HIV) and AIDS (Jordan, Fischhoff, Bruine de Bruin, & Downs, 1997). Briefly, we are finding that (a) some links (e.g., between own health and death, between sexual acts and disease transmission) are repeated everywhere, (b) some links (e.g., the role of most visceral factors, the benefits of sex) are seldom mentioned, and (c) some commonly reported facts (e.g., AIDS is caused by a virus) appear nowhere in the influence diagram. This pattern of communication would be justified if (a) the repetition provides essential reinforcement, rather than turning teens off; (b) the omitted material goes without saying, so that teens spontaneously infer its implications on their own, and (c) the off-diagram material provides theoretical background that helps teens integrate the full picture (e.g., by deriving the multiple implications of dealing with any virus-borne disease).

A Model-Driven (or "Mental Models") Research Program

What's Worth Knowing?

Providing information is a significant portion of many interventions intended to reduce vulnerability (for adolescents or anyone else). Defining the domain of discourse is

the critical initial step in such communication. Without it, one risks the chaotic selection of material that seems to characterize many communications about risks. People are ill-served by messages that repeat what they know and omit what they don't. The combination may not only fail to advance their understanding, but may also contribute to a false sense of confidence ("I guess I know everything that they have to tell me on this topic"), while reducing the credibility of the communicators ("Why are they repeating that material? What do they think I am, an idiot? What right do they have to waste my time?").

Over the past decade, our research group has developed an approach to communication that begins with a formal model of "what needs to be known," continues with interviews designed to reveal what people already know, and attempts to close the gap between the two with targeted communications providing that specific information (whose effectiveness is tested with similarly derived evaluation procedures). Because we are comparing people's mental representations of a domain with that in a formal model, we have called this a "mental-models" approach—recognizing that a variety of psychological approaches bear similar names (Bartlett, 1958; Johnson-Laird, 1983; Rouse & Morris, 1986). Initially, we worked on technological and environmental hazards, where the risks lay in natural or engineered processes and the role of human interventions could be limited to a few overt acts (Morgan, Fischhoff, Bostrom, Lave, & Atman, 1992). Our examples include radon, climate change, electromagnetic fields, and the use of nuclear energy sources in space. In each case, we produced formal models, descriptive data, print communications, and evaluation procedures. Our "hit" is a 32-page brochure on the health effects (if any) of 60-Hertz electromagnetic fields, some 200,000 copies of which have been sold to date (at cost, for the sake of preserving academic neutrality in this highly polarized area).

What needs to be known depends on the problem that people are facing. Within a domain, people often face a continuum of situations. In the best-structured ones, people just need summary statistics regarding risks or benefits. When those statistics arrive, recipients can "compute" the likely outcomes of their possible actions. In the least structured situations, people are just trying to create a mental model of the processes by which risks are created and controlled. That knowledge can give them a justified feeling of cognitive competence, as well as the ability to see when decisions are needed and how they can be formulated.

Well-Structured Decisions

The process for creating a formal model of an imminent decision is well-worked, but somewhat daunting. Using the tools of decision analysis (Raiffa, 1968), one should identify the possible courses of action, assess the probability of the significant consequences contingent on each choice, assess the relative attractiveness of those consequences, and combine these considerations using a proper decision rule in order to identify the best course of action (or the set of best options, among which one cannot discriminate). Although decision analyses are common for corporate and governmental decisions, they are rarely provided for the decisions of ordinary individuals. At best, one might find analyses of the circumstances facing classes of individuals, sharing some range of circumstances (affecting the options available and their likely effects) and common values (affecting the trade-offs they would make among the effects). Although better than nothing, such analyses nonetheless run the risk of providing unduly universal advice unless, fortuitously, one size fits most of the individuals in the assigned category.[9]

Where such modeling is justifiable, an important component involves examining the sensitivity of choices to the precision of estimates. Commonly one finds that only a few of the many potentially relevant variables really matter, and, even for those, a range of values will lead to the same conclusions (von Winterfeldt & Edwards, 1986). For example, Merz, Fischhoff, Mazur, and Fischbeck (1993) modeled the decisions facing candidates for carotid endartarechtomy. Scraping out the main artery to the brain can reduce the risk of stroke for individuals with arteriosclerosis there. Were there no side effects (and were money no object), every candidate would undergo the procedure. Unfortunately, it can also cause many problems, including iatrogenic strokes. The modeling showed, however, that few of these potential problems mattered for very many patients. For about 15%, the benefits would be outweighed by the risks of dying from the surgery; another 5% or so should decline surgery on learning about the risks of stroke and neurological deficit. If those side effects were not enough to tip the balance, then the rest would not. Arguably, physicians seeking informed consent should focus on ensuring that patients understand the probability and meaning of these few risks (e.g., what life is like for individuals with those specific neurological problems)—without denying access to any other information.

Ill-Structured (Pre-)Decisions

The components of a decision analysis describing a well-structured decision, summarize portions of the complex processes depicted in an influence diagram. The consequences in a decision analysis are variables in the influence diagram that have particular importance. The probabilities of those consequences reflect the initial conditions of a particular situation (as represented in the values of precursor variables). People's preferences (governing potential trade-offs) are reflected in the weight afforded risks, benefits, norms, and so on, in the integration process; they, too, would be set for a given individual or class of individuals (and might, to

[9] Fischhoff (1992) reviews these risks in general terms, with a specific focus on advice to women with respect to reducing the risks of sexual assault. McNeil, Weichselbaum, and Pauker (1978) show how such analysis can reduce the unwarranted imposition of physician values in treatment decisions regarding lung cancer, in a domain where the distributions of values for physicians and patients are relatively distinct.

some extent, be predicted from preceding variables). The options reside in particular nodes. In order to understand the situations facing individuals, to predict their responses, and to provide them pertinent information, we need to characterize these focal elements of the influence diagram for them. Decision analyses provide such summaries.

People are often just trying to get their bearings, however, in anticipation of possible future decisions. In those circumstances, they need to understand the big picture offered by the influence diagram as a whole. They need to figure out what factors determine the risks and possible benefits, as well as how those can be managed. They need to understand their own psychological processes in order to manage themselves as part of the process (e.g., collecting additional information, exercising proper caution, controlling visceral responses). Much of this coping goes on even when no decisions are pending. Often, people are just trying to follow the action, identify decision points, monitor the outcomes of previous decisions, counsel friends, evaluate information sources, acquire self-efficacy, make sense of advice, and so on. The efficacy of their decision making should depend on the accuracy of their mental models of the overall process. These "mental models" lack the computational possibilities of a formal influence diagram. They do have the pieces that people can assemble when making inferences about particular cases, however. People are vulnerable when pieces are missing or misunderstood. In a sense, they need to know what the experts need to know in order to predict how the system will respond to their actions. As a result, creating an influence diagram is a necessary first step to helping people to understand what they are facing.

What's Known (or Believed) Already?

Well-Structured Decisions

Do they have the pieces right? Any test of teens' knowledge should begin with an analysis of what information matters, focusing on the decisions that they actually face and the consequences that matter to them. Knowledge tests should then focus on information identified as critical. Questions eliciting these beliefs must be much more precise than typical vague survey questions, such as "How likely is it to get AIDS through sex with someone with AIDS?" (Gerrard, Gibbons, & Bushman, 1996) Logically, one cannot answer such a question without additional details, such as how much sex and of what kind (e.g., oral, anal, with what kind of protection and partner?). We have asked teens to think aloud as they answer several such questions. On average, the teens wanted half a dozen additional details, indicating that they spontaneously realized that the questions were greatly underspecified. If such vague questions appeared on a test, respondents would have to guess the missing details. Then, investigators would have to guess how respondents had read between the lines of these deceptively simple questions (Fischhoff, 1994, 1996). Under those conditions, it would be hard to know what teens believe.

Even with clearly specified questions, answers are difficult to interpret unless quantitative response modes are used. The interpretation of verbal quantifiers, such as "likely" and "rarely," varies by individual and context (Budescu & Wallsten, 1995; Cohn, Schydlower, Foley, & Copeland, 1995). Some very interesting science describes the determinants and implications of this variability; however, that research cannot rescue precision from ambiguity. In our work, we routinely use a graphic response mode that presents probabilities from .01 to 1.0 on a linear scale and smaller ones on a 6-order log scale. With a little instruction, even high-risk (e.g., incarcerated) teens seem able to use it in plausible ways.[10]

Using this response mode, along with well-defined questions, we have found, for example, that teens (and college students) greatly exaggerate the risks of HIV transmission, responding with values around .10 (for protected sex) and .50 (for unprotected). The same scale elicited much lower responses for risks like lightning strikes, suggesting that respondents really meant the high probabilities assigned to HIV transmission. With the same response mode, we have found little evidence of any uniquely adolescent tendency toward perceived invulnerability, but have found a frequent belief that single and multiple exposures present the same probability of exposure. We found that, like adults, teens have an imperfect understanding of the extent of their own knowledge, as measured by their judged probability of having answered questions regarding risks correctly. This task produced one of the few performance differences that we have found among the three groups whom we have typically studied: low-risk teens (recruited from school activity groups), parents of those teens, and high-risk teens (recruited from treatment homes and detention centers). For some reason, the high-risk teens were much less sensitive to the extent of their own knowledge (Fischhoff & Bruine de Bruin, 1997; Linville, Fischer, & Fischhoff, 1993; Quadrel, Fischhoff, & Davis, 1993).

Do they have the right pieces? For teens to bother assessing the probability of an event on their own, they need to realize that it could affect them or that their actions could affect it. Determining which actions and events are on people's minds is more challenging methodologically than determining what they believe about a topic that is drawn to their attention (the topic of the previous section, and most psychological research). We have used semi-structured interviews as a way to get at which issues occupy teens, recognizing that this is, at best, a rough approximation of

[10] We have recently cooperated with the staff of the new National Longitudinal Study of Youth to develop quantitative probability response modes, using a linear scale to elicit estimates of the perceived risks and benefits of various actions (e.g., having sex, finishing high school)

how they think when not talking with us. These interviews ask respondents to talk aloud about the domain defined by a formal analysis, gradually focusing them on general domains (e.g., options, uncertainties, values), while trying not to encourage any particular topics (Beyth-Marom et al., 1993; Beyth-Marom & Fischhoff, 1997; Fischhoff, 1992, 1996).

The value of these studies lies in the specific concerns that teens reveal regarding specific decisions—more detailed results than can reasonably be presented here. Looking across studies, however, some general tendencies seem to emerge regarding the structure of teens' decisions. One is that when asked, teens can generate good lists of options, consequences, and uncertainties. Where comparisons are possible, these lists are similar in length and contents as to those of adults. Moreover, teens' concerns are typically compatible with expert opinion—although they are often not expressed precisely enough to evaluate their accuracy rigorously. Thus, teens seem able to generate many of the pieces needed for thorough decision making. When they describe decisions in toto, however, their concerns seem to come out in a jumble, without clear order or decision-making rule.

In a study in which we asked young women to relate decisions in their own lives, we found that most decisions were described in terms of a single-action option that dominated teens' thinking (Fischhoff, 1996). This was especially true for decisions that these teens selected as being particularly difficult. As a result, the consequences of alternative options were much less developed. This pattern is consistent with the repeated observation that people (typically, adults) pay too little attention to opportunity costs—the benefits foregone by declining one option, when taking another (Thaler, 1993). We have found also that people (adults and teens alike) produce different kinds of consequences when asked to list what might happen when taking an action (skipping school to go to a mall) and when declining it, even though the two actions are complementary (i.e., the risks incurred by taking an action do not mirror the risks avoided by declining it) (Beyth-Marom et al., 1993). When asked why decisions were difficult for them, teens focused primarily on uncertainties about values (what they wanted) rather than on uncertainties about facts (what they could get). When asked what they did to help themselves make decisions, they described more rumination than seeking information or counsel. Thus, teens might be better able to disassemble complex situations than to reassemble them. (We have no comparable data with adults.)

Ill-Structured Decisions

Do they have the right pieces? In order to care about a quantitative estimate, people need to care about the variable that it describes. For example, the effectiveness of condoms against herpes only matters to someone who recognizes the existence of herpes, the possibility of consequences worth preventing, the modes of transmission, and so on. Although one could ask people whether they care about the elements of the influence diagram relevant to a decision, doing so would force attention to issues that might not otherwise attract their attention, while potentially missing misconceptions that were entirely outside the expert model. As a result, it makes sense to begin with open-ended interviews, allowing any intuitive theory to emerge (in respondents' natural language). We have used several approaches to this end:

- Have people think aloud as they assess the probability of deliberately ambiguous events. As mentioned, they frequently have a lot to add to the event specification. The missing details that they note suggest what matters to them. For example, we have found that teens spontaneously requested (or made assumptions about) the amount of exposure when estimating many risks (e.g., the probability of getting into an accident after drinking, the probability of lung cancer from smoking), but not the risks associated with sexuality (e.g., the probability of getting AIDS or becoming pregnant). These results suggested that the notion of cumulative risk from discrete, low-probability events is somehow missing from teens' repertoire of concepts (Fischhoff, 1996; Luker, 1975).
- Have people list the options, consequences, and sources of uncertainty in a class of situations, within which decisions might arise. In studies focused on preventing sexual assault, lay responses seemed to reveal greater sophistication than was assumed by expert advice givers (Fischhoff, 1992). Our subjects also held somewhat different values than were imputed to them by those experts, affecting the relevance of the facts that could be made available to them.
- Have people describe how risk processes evolve and are controlled, gently nudging them around the different areas of an influence diagram (Bostrom, Fischhoff, & Morgan, 1992). A typical interview begins with very general cues, creating little risk of putting new ideas into people's minds, but considerable risk of missing ideas that are there already. As the interviews proceed, the probes become more directive, increasing the risk of reactive questioning.

Using the last of these approaches, we have recently concluded hour-long interviews with a diverse set of 80 teens regarding the risks of HIV/AIDS. Whatever their life experiences, these teens seemed to know something about most of the major pieces of the HIV/AIDS puzzle, as would be depicted in an appropriate influence diagram (an AIDS-focused variant of Figure 4) (Fischhoff & Downs, 1997). Thus, the great volume of HIV/AIDS communications directed at young people has succeeded in conveying what the

main issues are. By contrast, we have begun a series of analogous interviews with young women regarding other STDs. To date, they seem to know very little, in response to our open-ended questions and gentle prompts. These teens hesitated to say very much even about those relationships for which plausible guesses might be deduced from general principles (or by analogy with HIV/AIDS). As a result, we have shifted the research to eliciting their mental models for the processes governing their control over their sexual activity, with an expert model that elaborates on the lower left and upper-right corners of Figures 3 and 4.

Do they have the pieces right? Having the right pieces is no guarantee of having the pieces right. In our initial mental-models study, we found that people (adult homeowners) knew that radon was a colorless, odorless, radioactive gas, but not that its radioactivity was short-lived (Bostrom et al., 1992). Erroneously believing that radon permanently contaminates whatever it touches needlessly discourages people from testing for it. Indeed, some respondents volunteered that there was no point in learning about a problem that they could not solve. For radon, the missing pieces of the mental model are quite easy to understand: it decays quickly; as a result, it releases its energy quickly, which makes small concentrations dangerous, but also means that the problem disappears once the influx is stopped.

This general pattern is not uncommon. For topics that have received public attention, people often have much relevant information; however, its value is undermined by critical "bugs" in their understanding. Leventhal and Cameron (1987) found that confusion about hypertension's lack of visible symptoms interfered with patients' adherence to drug regimens; compliance improved when it was explained to them how ill they could be without feeling, in effect, hyper or tense. McIntyre and West (1992) found that (Scottish) teens all knew about the importance of "safer sex," but disagreed considerably about just what that meant. If teens realize this underlying confusion, they may hesitate to act, or lack the confidence needed to press the point with partners, or cut themselves some dangerous slack, when deciding just what might be safe. If they do not realize their confusion, then they may unwittingly act unsafely.

In our own interviews, we frequently find such false fluency. When we ask teens to elaborate on terms and principles that they volunteer, they often either cannot do so or else report ideas rather different than one might assume (or hope). For example, teens know that "clean needles" are important, but describe cleaning practices whose actual safety varies widely. In response to being asked how risks depend on the amount of exposure, teens typically respond with "you can get it the first time." It is unclear what else they infer from this mantra, regarding, say, what one can infer about the risks of subsequent exposure "for someone who hasn't gotten it the first time." When asked about "what might disrupt their plans to protect themselves from HIV?" many teens volunteer cautions about drugs and alcohol. This seemingly positive awareness appears, however, to conceal more complex beliefs about the role of alcohol. Perhaps reflecting their confusion about sexuality, young women sometimes describe alcohol as providing cover for unsafe acts that they would not undertake directly. Being drunk seems to make unsafe sex more acceptable, even for people who drink in order to release just those inhibitions (Margolis, Fischhoff, Bruine de Bruin, & Palmgren, 1997). In these cases and others, it seems as though we have succeeded in teaching teens the language of risk, but not its meaning.

Having determined what is worth knowing (as defined by the influence diagram) and what is currently believed, one can not only design targeted communications, but also evaluate their effectiveness in terms of a theoretically derived standard. Based on the research just reported, we are currently field testing an evaluation of HIV/AIDS beliefs with items matched to the links in the relevant expert model and focused on potential and pertinent misconceptions. We believe that the approach allows us to say, with relative confidence, that teens who are able to pass this test have the knowledge needed to deal with HIV/AIDS (Downs, Bruine de Bruin, Palmgren, & Fischhoff, 1997).

Conclusions

A minimal standard for an ostensibly comprehensive approach is being able to pass what might be called the "Esperanto test." Namely, the approach should be able to accommodate all the major features of the approaches that it purports to integrate, even if some of their poetry is lost in the translation. When people (or theories) have trouble communicating with one another, providing that common ground can have value. However, the exercise of integration might also reveal some fundamental structures (in the problem domain) and provide some worthwhile insights (into how people behave within it). That is our hope here. The reader will have to judge our success.

Creating formal models of the situations facing teens (or anyone else) is a sign of respect for the complexity of their predicament. It can reduce the risks of unduly simple or misdirected evaluations and interventions. It says something about the criticality of the failings that are inevitable in anyone's performance in complex domains. It might facilitate the integration of research from various traditions, each necessarily restricted to a subset of issues—as is our own. Within these constraints, we see the following picture emerging regarding adolescent vulnerability.

When teens are allowed (and encouraged) to express themselves in their own terms, they reveal complex beliefs regarding topics that concern them. These beliefs often bear at least a rough correspondence to the scientific facts and adult views of the topics, although deeper probing may reveal significant (and unrecognized) confusion lurking under their fluency in using the language of risk (e.g., "safe

sex"). In all these ways, teens are not all that different from adults. As the modeling perspective reveals, however, vulnerability is a function of both person and situation. The situations facing teens may be particularly fraught with peril. As a result, the same level of functioning (or malfunctioning) may leave them much more vulnerable than are adults with the same cognitive abilities.

Some of those complications arise with individual risks. For example, the processes determining an individual's risk of sexually transmitted diseases are potentially quite complex, so that many mistakes could pose peril (e.g., misjudging a partner's history, underestimating population prevalence, overestimating the interpretability of symptoms). That complexity is greatly reduced for individuals with stable relationships; there is less to know and a greater opportunity to know it (although surprises are always possible). Teens (or others) with rapidly changing partners and practices (serial monogamy or serial celibacy) have a lot more to know, hence many more opportunities to be undermined by bugs in their knowledge.

The complexity of sexual decisions is one part of teens' burden of freedom. Their relative autonomy means that they often face many such decisions. Over a year or two, they may be making potentially fateful decisions in diverse domains, each posing its own (and interrelated) complexities. They need to make decisions about drugs, smoking, careers, friends, religion, violence, crime, and so on, with varying degrees of reversibility. Most adults have relatively set patterns for many of these topics. To take a baseball analogy, teens may have the same fielding percentage as adults, but a lot more chances come their way, including many hard ones. Moreover, they live such open lives that there may be fewer opportunities to hide their mistakes. Adults might prove as vulnerable, if they took more fateful chances—witness the mixed experiences of our colleagues undertaking their first serious investment, adventure travel, or midlife romance.

Finally, one must ask whether people actually get to the point of making deliberate choices where they can bring their knowledge and cognitive skills to bear. Although our evidence is incomplete, we believe that teens may have particular difficulty here. Any tendency toward impulsivity would undermine the role of cognition in teens' behavior. Conversely, any perceived difficulty in making cognition "work" might make teens more impulsive. Indeed, the very complexity of teens' thinking about their choices may work against them, unless this analytical ability is accompanied by a comparable synthetic one. What we hear, between the codable responses of our interviews, are teens trying very hard to make sense of the complex situations facing them, but having difficulty putting the pieces together and reconciling the conflicts in their values and the uncertainties in their perceptions. At the margin, decisions that cannot be resolved cognitively may tend to be resolved viscerally—as teens drift toward situations where fear, anger, or passion take over. If so, then the impulsivity of youth may be an effect, rather than a cause, of imperfect decision making.

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