

Fig. 12. Perceived probability, as judged by 254 9th to 12th graders, that a sexually active teenage girl would be at risk for sexually transmitted infections, compared to published estimates of risk (based on Reyna & Adam, 2003, and unpublished data).

found that perceived benefits were a significant predictor of a broad range of risky behaviors (from sexual to financial), but perceived risks were not significant (see also Ben-Zur & Reshef-Kfir, 2003). Only one study found that perceived risk was a better predictor of behavior than perceived benefits, but even that study found that both were significant (Rolison & Scherman, 2002). Thus, as rational decision-making theories suggest, consideration of the role of benefits is important in predicting adolescent risk taking: Perceived benefits may loom larger than perceived risks and offset them.

In summary, the key descriptive findings regarding adolescents' perception of risks are these:

- Much like adults do, most adolescents exhibit an optimistic bias, in which they view their own risks as less than those of comparable peers
- Research with adults suggests that this optimistic bias is probably due to egocentric focus rather than motivational factors, but little research on this point has been done with adolescents
- Objectively higher-risk groups sometimes estimate their risk as higher, and sometimes as lower, than lower-risk groups do, but different ways of asking questions change the answers
- The role of experienced outcomes may also explain these variable findings but preliminary evidence on this point is meager

- The optimistic bias is no more prevalent in adolescents than it is in adults, and, indeed, adolescents perceive themselves as more vulnerable than adults do
- When subjective and objective estimates of risk can be compared, adolescents tend to overestimate important risks (although they may underestimate harmful consequences and long-term effects, such as addiction; Weinstein, Slovic, & Gibson, 2004)
- Despite overestimation of risks, perceived benefits may drive adolescents' reactive behaviors and behavioral intentions, thereby accounting for risk-taking behaviors

DEVELOPMENTAL DIFFERENCES IN JUDGMENT AND DECISION MAKING

Précis of Developmental Findings Discussed Thus Far

Throughout this monograph, we have pointed out robust developmental trends. Compared to adults, children and adolescents have been found to be less able to delay gratification, inhibit their behavior, plan for or anticipate the future, spontaneously bring consequences to mind, or learn from negative consequences; and adolescents do not view consequences as being as harmful as adults do, especially if risky behaviors are engaged in only "once or twice." Children and adolescents also behave more impulsively (beyond individual differences that may linger into adulthood), reacting to immediate temptations without thinking and discounting future rewards more heavily than adults do, and their goals evolve in predictable directions that promote healthier long-term outcomes. Brain maturation is incomplete in adolescence, and changes in particular structures of the brain have been linked (correlationally) to these developmental differences in behavior.

Cognitive differences include a shift toward categorical or qualitative gist-based thinking, which explains increases in cognitive illusions with age (reflecting greater social knowledge and other globally adaptive but locally flawed thinking processes); increases in risk aversion in laboratory tasks (degrees of risk and reward matter less with maturity, compared to winning something versus nothing); and developmental differences in how degree of harm is viewed (adults do not make as fine-grained distinctions between experimenting with risky behaviors once or twice and experimenting more often). Thus, some risk taking in adolescence may be the result of quantitative trading off of benefits against risks, which gives way to more categorical risk avoidance with age. We have argued that developmental trends can be used as clues about what is rational; specific behaviors or thought processes that increase with maturity and experience are likely to be more advanced than those that decrease.

Because of the developmental differences that we have described, highly sophisticated logical and probabilistic reasoning competence, which can be demonstrated in children as young as 5 and 6 years old, is often not manifested under real-world

conditions of risky decision making. The fact that the competence is present, albeit in a dormant form, could be exploited in prevention programs. Contrary to popular wisdom, adolescents see themselves as more vulnerable than adults do, and they typically overestimate important risks. This overestimation appears to decline after early adolescence, presumably as exploration increases and rare negative consequences are not experienced, encouraging complacency.

Development of Risk Preference, Probability Judgment, and Risky Decision Making

Many of the developmental differences we have discussed thus far are contingent on knowledge and experience. For example, younger adolescents are likely to perceive risks as being high because of health curricula designed to reduce risk taking (Fischhoff, 2005). As adolescents become older, exploration increases, and risk estimation may decrease because adverse outcomes are not experienced or are experienced as neither immediate nor catastrophic. Such effects are contingent because different developmental trajectories could be expected with different exposure to information about risks. More fundamental differences have to do with changes in understanding of risk and probability, and in the processes of decision making, as adolescents mature.

A review of studies of children's and adolescents' understanding of risk and probability reveal three major theoretical approaches (for reviews, see Hoemann & Ross, 1982; Reyna & Brainerd, 1994): neo-Piagetian (logician), information-processing (computational), and fuzzy-trace theory (intuitionist). Dual processes have been assumed in all three of these approaches so their levels of theoretical complexity are roughly comparable. (The latter is an important consideration because no one approach is destined to be more successful because it uses more complex machinery.) In the first two, logic and analytical computation are seen as the zenith of development, and each is contrasted with developmentally primitive, intuitive thinking. Although the essence of advanced thought is formal logic for neo-Piagetians (Keating, 1980; Ward & Overton, 1990) and efficient information storage, retrieval, and processing for computationalists (Moore, Dixon, & Haines, 1991; Schlottmann, 2000, but see 2001; Schlottmann & Anderson, 1994), both types of theorists describe good decision making in terms similar to behavioral decision theory. That is, good decision making involves systematically and exhaustively considering the probabilities and outcomes or consequences associated with each option; multiplicatively combining these probabilities and outcomes; and choosing the option with greater expected utility, according to the values and goals of the individual. Hence, development involves acquisition of precise quantitative rules and improvements in memory capacity or logical reasoning (or both), which allow the weighing of more quantitative dimensions, more systematically (e.g., Hoemann & Ross, 1982; Siegler, 1991). For excellent reviews of developmental research on judgment

and decision making, see Jacobs and Klaczynski (2002, 2005) and Haines and Moore (2003).

Developmental data pose two serious problems for these views. The data in question are results showing early precocity in judgment and decision making and results showing late-persisting cognitive illusions (Jacobs & Klaczynski, 2002; Reyna & Brainerd, 1994). Regarding early precocity in probability judgment, functional measurement techniques have revealed subtle quantitative processing of probabilities (i.e., taking into account the ratio of numerical frequencies to estimate probabilities) much earlier than predicted by neo-Piagetian or information-processing theories (e.g., Acredolo, O'Connor, Banks, & Horobin, 1989). Other methodological advances have similarly shown quantitative trading off for probability judgments in children as young as 5 or 6 (Davidson, 1991; Jacobs & Potenza, 1991; Kerkman & Wright, 1988). Trading off of probabilities and magnitudes of outcomes in choice has also been demonstrated in young children (Reyna, 1996; Reyna & Ellis, 1994; Schlottmann, 2000, 2001; Schlottmann & Anderson, 1994). It should be noted that early precocity is more compatible with information-processing than with neo-Piagetian theories because of the stage assumptions of the latter (Brainerd, 1981). Using an information-processing approach, Klayman (1985), for example, highlighted continuities between 12-year-olds' multiattribute decision making in a bicycle-selection task and adults' decision making. Nevertheless, both information-processing and neo-Piagetian theories explicitly predict that young children lack the memorial and reasoning competence to make accurate probability judgments or to properly trade off probabilities and outcomes in decision making, a prediction that runs counter to the findings of published studies. Indeed, later research on the same multiattribute task used by Klayman (e.g., Davidson, 1991) has shown that younger children are more likely than are older children and adults to systematically and exhaustively consider attributes, reversing the predicted developmental trend.

Regarding results concerning cognitive illusions, a problem for both neo-Piagetian and information-processing developmental theories is that cognitive illusions demonstrated in adults have been found to increase throughout childhood and adolescence—again, the reverse of the predicted developmental trend (Table 3). To take but a few examples, the representativeness heuristic in probability judgment is illustrated by weighting individuating information (often information that allows an individual to be easily stereotyped) more than appropriate quantitative information such as relative frequencies. For instance, Jacobs and Potenza (1991) showed that first graders could correctly make object and social judgments based on relative frequencies: If there were five black socks and three blue socks in a drawer, children correctly predicted that drawing a black sock was more likely than drawing a blue sock. As children became older, however, they were increasingly likely to reject social judgments based on relative frequencies in favor of stereotypes; for example, judging pretty, outgoing girls as more

likely to be cheerleaders regardless of the low frequency of cheerleaders. In the absence of stereotypes, object judgments remained unbiased. Increases with age in the availability heuristic (judging that events that come to mind easily must be more probable than events that are difficult to think of, e.g., that death by homicide is more likely than death by cardiovascular disease because the former is easier to think of due to media coverage), the conjunction fallacy (judging that a conjunction of events is more probable than either event by itself, e.g., that being killed by a drunk driver is more likely than being killed in any vehicular accident, including those involving drunk drivers and those not involving drunk drivers), and other cognitive illusions in probability judgment have also been demonstrated (e.g., Davidson, 1995).

Similarly, Reyna and Ellis (1994) have shown that framing effects in decision making—shifts in choices for the same options when they are described in terms of gains rather than in terms of losses—increase during childhood and adolescence (reflection effects, shifts in choices when gains and losses *actually* differ, have been found early in childhood; Reyna, 1996; Reyna & Mattson, 1994; Rice, 1995). Using detailed visual props and instructions, children were presented with choices such as the following: a choice between one toy for sure versus a 50% chance of winning two toys and a 50% chance of winning zero toys (communicated by a spinner with two colored halves and with zip-lock bags containing two toys on one half and an empty bag on the other half). Preschoolers made choices based on the quantitative bottom line involving both the probability and outcome dimensions: Although they were generally risk seeking, preschoolers modulated choices between sure things and risky options based on the degree of risk and on the number of prizes. When risk was too high, they chose the sure but smaller number of prizes. Elementary schoolers based choices mainly on which option offered more prizes, ignoring the dimension of magnitude of probabilities. Adolescents were the most likely to be qualitative reasoners, basing choices on neither the degree of risk nor on the number of prizes, especially for small numbers of prizes; instead they preferred the sure option in the gain frame, because winning something for sure was better than taking a risk and maybe winning nothing. They preferred the risky option in the loss frame because possibly losing nothing was better than losing something for sure. Adults also have been shown to prefer making such decisions qualitatively rather than quantitatively, consistent with fuzzy-trace theory (Reyna & Brainerd, 1991b, 1995; neural-network models have recently incorporated similar assumptions, Frank & Claus, 2006). These kinds of counterintuitive findings that seem implausible on their face but are predicted by theory are the most informative in testing alternative explanations for behavior. Studies have been reported in which not all of these illusions increased with age (e.g., Klaczynski, 2001), but even these studies often fail to confirm the age decline predicted by Neo-Piagetian or information-processing theories. Naturally, poor reasoning has also been

found to decline with age (e.g., Klaczynski & Cottrell, 2004); the contradiction between increasing cognitive competence and increasing intuitive illusions with age (e.g., Arkes & Ayton, 1999) is precisely what dual-process theories attempt to explain.

How does fuzzy-trace theory accommodate the seemingly contradictory trends of early precocity and increasing cognitive illusions with age that we have discussed? These contradictions can be demonstrated within a single study. For example, older children can be shown to make accurate judgments and decisions about objects but fail to use the same concepts to make accurate social judgments and decisions (i.e., they exhibit task variability; Jacobs & Potenza, 1991; Reyna & Brainerd, 1994; Schlottmann, 2001). However, younger children are able to demonstrate sophisticated quantitative competence in social judgment tasks, and, according to fuzzy-trace theory, they would be more likely to approach such a task quantitatively than older children and adults, who are more likely to be qualitative gist processors. Cognitive illusions are generally based on qualitative gist-based processing—for example, of social stereotypes and other interpretive processing (e.g., specific evidence for gist-based processing has been obtained in the tasks listed in Table 3). The social judgments that elicit illusions, for example, are based on cultural knowledge of social stereotypes that increases with development. Hence, fuzzy-trace theory accommodates these seemingly contradictory results of early precocity and late-persisting illusions because it is a dual-processes theory; each process is necessary to produce one of the contradictory developmental trends, and indeed, particular assumptions about those processes were initially used to predict both trends (e.g., Reyna & Ellis, 1994; see also Reyna, 2005).

On the one hand, according to fuzzy-trace theory, early precocity is explained by the finding that analytical competence is present early; children who cannot even count, let alone multiply, are able to trade off mentally using perceptual estimations of magnitudes. The data show that children grasp the idea that probabilities trade off against magnitudes of outcomes, they perceptually estimate those magnitudes, and they perform rough mental multiplication (e.g., Huber & Huber, 1987; Reyna & Ellis, 1994; Schlottmann, 2001). For example, children estimate relative areas of spinners in a probability task and magnitudes of piles of prizes in a decision-framing task, and they make decisions roughly according to expected value (provided that the task has the right perceptual supports, e.g., that probability can be perceptually estimated by comparing colored areas of spinners and magnitudes of outcomes can be perceptually estimated by comparing the sizes of piles of prizes; Reyna & Brainerd, 1994).

On the other hand, according to fuzzy-trace theory, increases in cognitive illusions in childhood and adolescence are predicted because of the increased reliance during this period on intuitive qualitative (i.e., gist-based) thinking that reflects knowledge, including social knowledge, and experience (e.g., Reyna, 1996; Reyna & Adam, 2003). The increased reliance on intuitive qualitative thinking also explains surprising increases

in false memories during childhood and adolescence that parallel increases in false reasoning or illusions, and are explained on similar grounds (Reyna, Mills, Estrada, & Brainerd, in press). (Factors such as emotion and social values also figure in fuzzy-trace theory, but space does not permit their elaboration here; see Reyna, 2004a and Reyna et al., 2005.) Thus, fuzzy-trace theory is a dual-processes approach that assumes both early analytical competence and developmental increases in intuitive reasoning (as a result of greater experience and knowledge), and consequent increases in cognitive illusions based on gist (Table 3). These developmental assumptions are the opposite of those of information-processing (computational) and neo-Piagetian (logicist) theories.

What are the implications of these differing theories for interventions to change thinking and reduce adolescent risk taking? As we have discussed, dual processes offer a solution to the dilemma that advanced reasoners seem to exhibit both greater analytic thinking and more pronounced intuitive cognitive illusions. The difference between fuzzy-trace theory and traditional behavioral decision theory, however, is that the former generally encourages simple gist-based intuition as a way to improve thinking (e.g., Lloyd & Reyna, 2001; Reyna, 1991), whereas the latter encourages information-rich quantitative thinking as a way to improve thinking. Moreover, the most advanced thinking in fuzzy-trace theory is not necessarily deliberative and analytical but, rather, unconscious and intuitive, and vice versa for behavioral decision theory. Consistent with the former, Dijksterhuis et al. (2006) recently demonstrated that for complex decisions, such as buying a car, nondeliberative thought produced better results than conscious deliberation did. Thus, fuzzy-trace theory offers a view of decision makers that is antithetical to classical decision theory's probability-calculating, utility-maximizing individuals.

The implications of these different theories of development for reducing risk taking are straightforward and divergent. Neo-Piagetian theory suggests that the formal, abstract thinking required for ideal decision making is largely absent in early adolescence and, for that matter, in adulthood for many (Keating, 1980; Winer & McGlone, 1993)—and it cannot be easily taught. Maturation through stages offers the only hope for reducing risk taking (i.e., most adolescents will naturally grow out of this stage of development), and standard health curricula, with their emphasis on accurate risk perceptions and analytical deliberation about risks and benefits, should be of little use until quite late in development (for a detailed discussion of this “developmental learning” perspective, see Inhelder, Sinclair, & Bovet, 1974). Information-processing (computational) or behavioral decision theories, in contrast, suggest that instruction in careful deliberation can be taught as a matter of explicit description of options, thorough consideration of consequences, and rational rules for combining probabilities with outcomes (see also Moshman, 2004, for a not-dissimilar approach to rationality in terms of metacognition). As our earlier review of explanatory theories of

risky decision making and key findings indicates, adolescents appear to rationally consider risks and benefits to some extent in their decision making. Behavioral intentions, based on perceived benefits and risks, successfully predict some risky behaviors. Increasing perceptions of risks and decreasing perceptions of benefits would, in turn, be required to reduce risk taking. But a hallmark of behavioral decision theory is that perceptions of risks and benefits are accurate; if adolescents overestimate risks, for example, improving the accuracy of risk perceptions would logically increase risk taking—a rational decision, perhaps, but not necessarily desirable from a societal or long-term health perspective.

According to fuzzy-trace theory, however, mature decision makers should not deliberate about the degree of risk and magnitude of benefits if there is a non-negligible chance of a catastrophic health-compromising outcome (Baird & Fugelsang, 2004; Reyna & Ellis, 1994; Reyna et al., 2005; Fig. 13). (For research on what negligible or “nil” risks are, based on fuzzy-trace theory, see Stone, Yates, & Parker, 1994; but suffice it to say it is a fuzzy concept.) Consistent with this prediction, Baird and Fugelsang, for example, found that adolescents showed longer reaction time than adults in response to questions such as, “Is it a good idea to swim with sharks?” as well as more diffuse brain activation. Metaphorically speaking, adolescents should not deliberate about the number of bullets in the chamber of a gun in Russian roulette just because there is a high potential payoff. No amount of payoff can compensate for the possibility of death in Russian roulette (assuming that the decision maker is not destitute), and similar reasoning applies to the risk of HIV/AIDS. Because mature decision making involves gist-based qualitative reasoning (e.g., avoid catastrophic risk), per fuzzy-trace theory, adults do not trade off quantitatively under specific circumstances. Exhortations such as “it takes once” to become pregnant or contract AIDS do not mean that the probability is 100% but, rather, that the qualitative possibility of catastrophe is sufficient that the risk should be avoided. Similar reasoning explains why adults prefer sure things and avoid gambles even

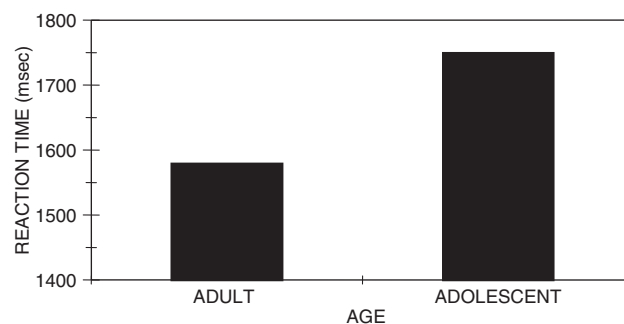


Fig. 13. Reaction time in milliseconds for adolescents and adults to questions such as, “Is it a good idea to set your hair on fire?”, “Is it a good idea to drink a bottle of Drano?”, and “Is it a good idea to swim with sharks?” (based on Baird & Fugelsang, 2004).

when expected values of gambles exceed that of the sure thing—when the gamble is taken once, decision makers will either end up winning something or winning nothing. The qualitative possibility of winning nothing is sufficient to avoid the risk, regardless of the probability of winning something (see Reyna et al., 2003).

The goal of instruction in fuzzy-trace theory, then, is to make gist-based decisions (involving risk-avoidant values) automatic and nondeliberative. Success in training reasoning using fuzzy-trace theory has been achieved with children (Reyna, 1991) and adults (Lloyd & Reyna, 2001), and experimentation is in progress on instruction to reduce adolescent risk taking. To be sure, the implications of fuzzy-trace theory and behavioral decision theory are diametrically opposed, the latter encouraging trading off risks and rewards and the former discouraging such trading off. Because some adolescent decisions appear to be reactive (as in behavioral willingness), rather than rationally deliberative (as in behavioral intentions), a combination of approaches could be more effective than either of them alone (Gerrard, Gibbons, Brody, Murry, Cleveland, & Mills, in press).

GENERAL DISCUSSION: IMPLICATIONS OF DATA AND DEVELOPMENT FOR RISK REDUCTION AND AVOIDANCE

Interventions to reduce risk taking have been developed from explanatory models, and those that combine multiple components have achieved limited success in changing behavior (see, for example, Baron & Brown, 1991; Kirby, 2001; Romer, 2003, for reviews). These components have traditionally included perceptions of risks, benefits, social norms, perceived control, and self-efficacy, as well as practiced skills, such as refusal skills for rejecting sexual activity (for a review of randomized controlled trials for interventions to reduce premature pregnancy and sexually transmitted diseases, see Reyna et al., 2005). Traditional models incorporate these components in a behavioral decision framework that, despite differences in individual models, generally emphasizes conscious behavioral intentions and expectations rather than unconscious emotional and cognitive reactions to environmental triggers. For some adolescents, the traditional models seem to apply; these adolescents take risks because perceived benefits outweigh risks, and long-term consequences are not considered or are undervalued. For other adolescents, the evidence indicates that behavioral willingness and perceptions of the gist or images involved in a decision determine risky behavior. These adolescents do not intend or expect to take risks, and their own rational deliberation might favor behaviors that are different than the actions they have taken impulsively or under the influence of emotion. Still other adolescents, and mature adults, apparently resist taking risks not out of any conscious deliberation or choice but because they intuitively grasp the gists of risky situations, retrieve appropriate risk-avoidant values, and never proceed

down the slippery slope of actually contemplating tradeoffs between risks and benefits.⁸

The policy implication for the first group of adolescents, the risky deliberators, is that traditional behavioral decision making approaches, such as health-belief models or the theory of planned behavior, should be effective in reducing risk taking, provided that adolescents can be convinced that risks outweigh benefits or that competing benefits are more desirable (e.g., playing sports, staying in school). This approach would backfire if, as is likely, adolescents discover that risks are lower than they believed or, for the third group of intuitive gist-based decision makers, that analyzing risks and benefits favors risk taking. The second group of adolescents, the risky reactors, will be unaffected by traditional interventions because risk taking for them is spontaneous and disjoint from rational contemplation of risks and benefits. Gist-based interventions could be more effective for the second and third groups—interventions that stress automatic (nonconscious) encoding of cautionary cues in the environment (getting the gist of risky situations) and repeated practice at retrieving and implementing risk-avoidant values in simulated contexts. Although research supports effectiveness of some pieces of such an intervention, this approach has not been widely extended to reducing risk taking in field-based studies. Clearly, development of psychometric instruments, including behavioral measures, that successfully distinguished the different kinds of risk takers and avoiders would be crucial for matching adolescents with the kinds of programs that are likely to be effective for them (although these mappings may change over time and decision domains, in contrast to those for stable traits such as thrill seeking).

Most traditional interventions, such as the ones we have just discussed, involve verbal instruction (although role playing and skills practice are increasingly used). However, recent laboratory research has shown that decisions reverse when risks are described verbally versus experienced as outcomes in a learning task. That is, risky options are avoided when they are described verbally but are preferred when outcomes are experienced (in both instances, risks are rare, such as for HIV infection, and accompanied by benefits). For this reason, the role of experience is increasingly prominent in theories of risky decision making. For example, intuitions about risky situations are generally not innate (although evolution factors into social perceptions) but, rather, arise mainly from social learning and experience. As dramatically illustrated in Figure 9, the ability to learn from

⁸Although we discuss these typologies of risk takers and avoiders as though they applied to different people (and there are broad developmental and individual differences), the truth is more complicated. A dominant decision-making approach may occasionally give way to a less preferred mode. For different decisions, the same person may be a risky reactor, a risky deliberator, or an intuitive (gist-based) risk avoider. Hence, the mature adult (or adolescent) may have lapses of maturity. The phrase “never proceed down a slippery slope” properly applies to decisions rather than people, and applies to those instances in which the decision maker has avoided the risky route. None of this should be interpreted to mean that there are not reliable differences across age groups and across individuals.