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Judgments about Risk and Perceived Invulnerability in Adolescents and Young Adults

Susan G. Millstein and Bonnie L. Halpern-Felsher
University of California, San Francisco

This study examined age differences in risk judgments and perceptions of invulnerability, by surveying 577 adolescents (grades 5, 7, and 9) and young adults (ages 20 to 30 years) for their judgments concerning natural hazards and behavior-linked risks. Adolescents were less likely than were young adults to see themselves as invulnerable, and only a small minority of adolescents evidenced such perceptions. Moreover, individuals' perceptions about the magnitude of their personal risk for experiencing negative outcomes showed an inverse relation to age. Most participants were inaccurate and significantly overestimated risks; this was especially true of adolescents. These patterns of age differences were consistent across different types of risks and sociodemographic configurations. The results pose a challenge to conventional wisdom concerning adolescents' perceptions of risk and have important implications for theory, programs, and policies related to adolescents.

Judgments about risk are viewed as crucial factors in individuals' decisions concerning health-damaging and health-promoting behaviors. As such, they are included in most theoretical models of health behavior (Azjen, 1985; Bandura, 1994; Fishbein & Ajzen, 1975; Kanfer, 1970; Rosenstock, 1974; Triandis, 1977) and play a fundamental role in many intervention programs and health education campaigns (Beyth-Marom, Fischhoff, Quadrel, & Furby, 1991; Hansen, 1992). The ability to judge risks is also considered to be an essential element of decision-making competence by

Requests for reprints should be sent to Susan G. Millstein, University of California School of Medicine, Department of Pediatrics–Box 0503, 3333 California Street, Suite 245, San Francisco, CA 94143-0503. E-mail: shana@itsa.ucsf.edu

scientists and practitioners in diverse areas including the social sciences, medicine, public health, social work, law, and social policy (Byrnes, 1998; Gittler, Quigley-Rick, & Saks, 1990; Hodne, 1995; Janis & Mann, 1977; Scott, Reppucci, & Woolard, 1995).

Speculation about adolescents' lack of competence in recognizing and assessing risk has existed since the time of Aristotle. In both lay and scientific circles, adolescents are frequently portrayed as believing they are invulnerable to harm, a presumption that implies a compromised ability to judge risks. The theoretical basis for the assertion of adolescent invulnerability can be traced to Elkind (1967, 1978), who argued that when young adolescents first enter into formal operations, they become cognitively egocentric. Due to this egocentrism, the adolescent is hypothesized to hold an exaggerated sense of uniqueness and to believe in a "personal fable" — the view that one is special and in some way immune to the natural laws that pertain to others. The personal fable, with its associated perceptions of invulnerability to harm, is thought to explain adolescent risk taking. As the individual matures into middle and late adolescence, egocentrism and perceptions of invulnerability are expected to diminish.

Elkind's theory (1967, 1978) is intuitively appealing, but it has not fared well in empirical tests. Egocentrism does not appear to be linked to young adolescents' transition into formal operations (Gray & Hudson, 1984; Jahnke & Blanchard-Fields, 1993; Lapsley, Milstead, Quintana, Flannery & Buss, 1986), nor is it limited to adolescence (Frankenberger, 2000). Research has also failed to find the expected positive relation between egocentrism and perceptions of invulnerability (Dolcini et al., 1989). In an attempt to address these and other problems with the original theory, alternative theoretical reformulations have been offered to explain the personal fable (Lapsley, 1993; Lapsley, FitzGerald, Rice & Jackson, 1989; Lapsley & Murphy, 1985). The reformulations, which reallocate the origins of adolescent egocentrism to social cognitive and ego development, preserve the expectation that early adolescents demonstrate a heightened sense of invulnerability that decreases as adolescents mature. However, empirical tests using improved measures of the theoretical constructs have failed to show these expected age effects (Lapsley et al., 1989). Furthermore, as an explanation for adolescent risk taking, both the original and reformulated theories appear problematic, because early adolescence is not the period of greatest risk taking (Lindberg, Boggess, Porter, & Williams, 2000).

Perceptions of adolescents as incompetent decision makers who are unable to adequately assess potential risks provide the basis for many legal limitations on adolescents' rights (*Bellotti v. Baird*, 1979; see also Gardner, Scherer, & Tester, 1989). At the same time, however, others view adolescents as being capable of making informed, competent decisions, with

capabilities equivalent to those of adults (Melton, 1984). Policies that allow adolescents to take part in research or to undergo certain types of medical treatments without parental permission reflect beliefs in adolescents' competence to judge risks (English, 1990; Gittler et al., 1990; Santelli et al., 1995). Thus, resolving these contradictory views of adolescents' capabilities has important and far-reaching implications.

Existing research on adolescent risk perception is not particularly helpful in resolving the debate.[1] Findings have been inconsistent and studies are rarely comparable (for a recent review, see Millstein & Halpern-Felsher, 2001). In studies that have examined age differences within adolescent samples, reported findings have included age-related decreases in perceived risks (Bernstein & Woodall, 1987); a U-shaped, curvilinear relation of age to risk judgments (Urberg & Robbins, 1984); inconsistent age patterns (Finn & Brown, 1981; Gochman & Saucier, 1982); and no age differences (Cohn, Macfarlane, Yanez, & Imai, 1995). Only two studies have directly compared adolescents' risk judgments with those of adults—an important comparison because it allows for the ability to identify whether adolescents' risk judgments are quantitatively different from those of legal adults. Cohn, Macfarlane et al. (1995) found perceptions of risk to be lower in adolescents than in adults. In contrast, Quadrel, Fischhoff, and Davis (1993) found perceptions of invulnerability to be more prevalent in adults than in their adolescent children.

The disparity among study findings is not surprising if the differences between them are examined, especially in terms of their measures of risk perception. For example, Quadrel et al. (1993), Gochman and Saucier (1982), and Urberg and Robbins (1984) all used probability assessments (i.e., the chance that an outcome will occur) to measure risk perceptions. In contrast, Finn and Brown (1981) and Cohn, Macfarlane et al. (1995) examined perceptions about harm (i.e., the amount of harm that would be caused).

Although differences such as these influence comparability across studies, more fundamental problems are evident that call into question the validity of many study findings themselves. The most serious of these is the failure to consider participants' behavioral experiences. Experience is a known source of variation in risk judgment (Gerrard, Gibbons, & Bushman, 1996; Halpern-Felsher et al., 2001; van der Plight, 1998) that varies by age as well. The failure to control for experience is further compounded when considering how risk judgments are typically framed. Eliciting meaningful risk judgments requires adequate description of the conditions under which the risks are being assessed. In the case of behavior-related risks,

[1] Studies on comparative risk assessments (i.e., optimistic bias) are not included.

this means making explicit linkages between the outcome ("What is the chance you will acquire an STD [sexually transmitted disease] . . .") and the behavior (". . . if you have sex without a condom?"). Risk judgments that simply ask about the chance of an outcome occurring without specifying the relevant behavioral antecedent conditions essentially measure different things depending on the behavioral characteristics of the respondent (Millstein & Halpern-Felsher, 2001; Ronis, 1992; Van Der Velde & Hooykaas, 1996). For this reason, studies on age differences are only interpretable if they use conditional risk judgments or, at a minimum, control for participants' behavioral experiences.

Other than the current study, only two others meet this criterion. Cohn, Macfarlane, et al. (1995) reported no differences among 13- to 18-year old adolescents in their perceptions of harm, but found that adolescents perceive less harm than did their parents. In contrast, Urberg and Robbins (1984) found that perceptions of smoking-related risks had a curvilinear relation to age in a sample of adolescents in grades 6 through 12. A strong inverse relation was characteristic of adolescents in grades 6 through 8; and a smaller, positive relation was found among adolescents in grades 8 through 12.

Although these studies are the most rigorous in terms of their consideration of behavioral experience, they are limited in other ways that were addressed in the current study. The adult participants used in the Cohn, Macfarlane et al. (1995) and Quadrel et al. (1993) studies were the parents (usually mothers) of the adolescent participants. In addition to creating problems of nonindependence between groups, parents who participate may do so because of special concerns about the child who is in the study. Parents of adolescents could also have heightened concerns about risk that are independent of actual developmental differences. For these reasons, the current study used a sample of unrelated, childless adults.

Urberg and Robbins (1984), like other researchers (Bernstein & Woodall, 1987; Finn & Brown, 1981), restricted the range of outcomes examined, focusing only on tobacco use. Thus, it is difficult to ascertain whether the patterns of risk perception that they reported are specific to one area or if they can be generalized across different kinds of judgments. Such information is important to understand the potential developmental nature of risk judgment. The current study improved on this limitation by including a range of natural hazards and behavior-linked risks.

Although there have been other frequently cited studies on age differences with relevance to the broader issue of adolescents' decision-making competence, they did not examine magnitude differences in risk judgment. These include studies that focused on the adolescent age group (Lewis, 1981) as well as several that compared adolescents and adults

(Ambuel & Rappaport, 1992; Beyth-Marom, Austin, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993; Chassin, Presson, Rose, & Sherman, 2001; Halpern-Felsher & Cauffman, 2001; Lewis, 1980; Weithorn & Campbell, 1982). Four of these studies reported age-related changes in individuals' awareness of and consideration of risks (Ambuel & Rappaport, 1992; Chassin et al., 2001; Halpern-Felsher & Cauffman, 2001; Lewis, 1981), while the remaining three found few differences. Reconciling these findings or applying them to answer questions concerning adolescent risk judgment is of questionable value, given the differences among the constructs they assessed.

The current study addressed three basic questions concerning adolescent risk judgment that remain unanswered. First, are there age differences in risk judgment and if so, what is the nature of those differences? Second, do adolescents' risk judgments differ from those of legal adults? Third, are perceptions of invulnerability to harm more prevalent in adolescents than in legal adults? This is the first study to address these questions in adolescents and unrelated adults, across a broad range of risks, controlling for the effects of behavioral experience.

METHOD

Participants

Adolescent participants (n = 433) included 125 fifth graders, 148 seventh graders, and 160 ninth graders (Table 1). Young adults (n = 144) between the ages of 20 and 30 years provided a comparison group of legal adults (Table 1). The mean ages of the three adolescent groups and the young adult cohort were 10.7, 12.7, 14.8, and 25.0 years, respectively. The gender distribution in the four age cohorts was similar; females represented approximately 50% of the fifth- and seventh-grade samples and 60% of the ninth-grade and young adult samples. Most of the young adults were in school (88%), and 50% were working at least part time. The number of years of parental education did not differ by age group but there was a shift toward a greater proportion of postbaccalaureate degrees among the fathers of the young adult participants, $\chi^2(6, N = 441) = 22.04$, $p < .002$; one half of the fathers of young adults had advanced degrees, compared with about one third in the younger age groups (data not shown). Although most young adults were able to report on their parents' educational level, approximately one half of the fifth-grade sample and one third of the seventh- and ninth-grader samples left the item blank, resulting in substantial missing data on this variable. In our experience, it is not unusual for adolescents to be unaware of the specifics of their parents' education. Nevertheless, it is possible that adolescents who are unaware of their

TABLE 1
Sociodemographic and Behavioral Characteristics of Study Participants

Characteristic	*Fifth Graders (N = 125)*	*Seventh Graders (N = 148)*	*Ninth Graders (N = 160)*	*Young Adults (N = 144)*	*p*[a]
Age, Mean ± *SD*	10.75 ± .44	12.72 ± .36	14.82 ± .42	24.97 ± 2.26	.000
Gender (female), %	49.6	50.0	60.0	62.5	*ns*
Ethnicity					.000
White, %	79.8	79.9	82.1	55.2	
Asian/Pacific Island, %	1.6	6.1	2.6	23.8	
Latino, %	4.0	4.1	2.6	3.5	
Black, %	2.4	.7	.6	5.6	
Other, %	12.1	9.5	12.2	11.9	
Father's years of education, *M* ± *SD*	16.0 ± 2.6	15.9 ± 2.7	16.1 ± 2.5	16.7 ± 3.0	*ns*
Mother's years of education, *M* ± *SD*	15.6 ± 2.5	15.8 ± 2.4	15.4 ± 2.7	15.4 ± 2.9	*ns*
Has had sex, %	N.A.[b]	6.1	12.7	82.6	.000
Has had unprotected sex, %	N.A.[b]	2.1	5.1	76.4	.000
Has drunk alcohol, %	21.1	43.8	76.9	97.2	.000
Has had six or more drinks of alcohol at one time	4.8	8.2	38.9	70.8	.000
Has driven with alcohol-impaired driver, %	23.4	32.7	44.3	77.6	.000

[a] Test for significance of overall group differences.
[b] Fifth graders were not asked about sexual behavior.

parents' educational level differ in some systematic way from those who had this information. The only notable demographic difference among the four age cohorts was ethnicity $\chi^2(15, N = 571) = 84.56$, $p < .0001$. Approximately 80% of the adolescents described themselves as White, compared with 55% of the young adults. The young adult cohort also had a larger proportion of individuals from Asian/Pacific Island descent (24%) than did adolescents (2–6%).

Procedures

Adolescent participants ($n = 433$) were recruited from geographically and demographically similar Bay Area public school districts in suburban northern California communities. Six schools participated. Information about the study was sent home and parents were asked to return a postcard indicating their interest in having their child participate. Those who did so were subsequently contacted by research staff who obtained

consent and enrolled the adolescent in the study. Consent from both the adolescent and a parent was obtained. Two different methods of initiating contact with parents were used. In the first, letters were sent to the homes of all fifth, seventh, and ninth graders enrolled in two of the participating schools. A majority of parents (61%) did not return postcards, even after a second request. This school-based approach yielded a low rate of participation (15%) in the populations sampled and yielded 241 participants (89 fifth graders, 130 seventh graders, and 58 ninth graders). In the second approach, which was used in the four remaining schools, recruitment activities took place at the classroom level. Teachers gave students information packets to take home, and packets were returned to individual teachers. This approach yielded a much higher return rate (approximately 98%) and participation rate (95%), and yielded 192 participants (36 fifth graders, 18 seventh graders, and 102 ninth graders).

A convenience sample of legal adults was recruited from three universities in the Bay Area via posted flyers, as well as by asking participants to name friends who might be interested in participating. Obtaining participants through the latter method could yield less representative samples, but in the current situation is unlikely to have done so because only a small proportion (approximately 3%) of the adult sample were recruited in this manner. The adult sample was restricted to unmarried individuals without children due to concerns that individuals who were married and/or parents might have a heightened awareness of risk due to these responsibilities, thus obscuring age differences due to cognitive developmental factors. Additionally, to minimize the potential for cohort effects, only legal adults between the ages of 20 and 30 years were sampled, resulting in a relatively homogeneous group for whom being single and without children were within normative limits.

To ensure that any resulting age differences were not due to differences in how participants were recruited, separate analyses of age-related effects were conducted for each of the two adolescent groups. These analyses showed no differences in the findings as a function of recruitment method. Therefore, analyses from the combined adolescent groups are presented in the Results section. For analyses of age differences within the adolescent sample, recruitment method was used as a covariate.

Participants completed the study questionnaire in group settings, either in classrooms or at off-campus locations. Administrations were conducted by research assistants who explained the survey and answered any questions that arose during the administration. The survey generally took participants between 60 to 90 min to complete. Refreshments were provided and participants were paid ($10 for adolescents, $15 for adults) for their time and effort.

Measures

Data were collected by self-administered questionnaire. Demographic information obtained from participants included age, birth date, gender, grade in school, race/ethnicity, and parents' level of education.

Risk judgments. Risk judgments concerning 14 outcomes were examined. Four items asked about the probability of dying from natural hazards (lightning, tornado, hurricane, and earthquake). Ten items dealt with negative outcomes associated with personal behavior: two of these focused on outcomes related to a relatively neutral behavior (jogging) and eight focused on outcomes due to personal behaviors of a sensitive nature (alcohol use and sexual behavior).

Participants' risk judgments were elicited by having them read scenarios that described a particular risk situation (see the Appendix). To minimize variability in how participants would interpret the risk situations (Quadrel, Fischhoff, & Palmgren, 1997) and to ensure that risk judgment differences were not a function of such interpretive differences, scenarios were highly specified. For example, in eliciting judgments about risks for STDs, the risk situation (having unprotected sex) specified both the type of sexual partner (someone you are in love with) as well as the number of unprotected episodes of sex.

With each scenario, participants were asked to imagine themselves in the situation and then to assess the chance (by using any percentage between 0% to 100%) that they personally would experience a specific outcome linked to that situation (e.g., "Imagine that you are at a picnic when a lightning storm strikes. What is the chance that you will die in the lightning storm?"; see the Appendix). Participants were shown examples of how to use the percentage scale.

Previous studies have shown that adolescents are able to use quantitative response scales in reasonable ways (Fischhoff et al., 2000). Advantages of the percentage scale include the provision of ratio level data, as well as the potential for generating less inconsistency of use across participants. Lexical expressions of probability, such as "likely" or "unlikely" appear to have great variability in meaning for both adolescents and adults (Beihl & Halpern-Felsher, 2001), and percentage estimates can reduce this variability (Cohn, Schydlower, Foley, & Copeland, 1995). However, little is known about the meaning that adolescents attribute to different percentage estimates.

Numeracy. Adolescents vary in their capacity to think and express themselves quantitatively, and these differences are related to how they use quantitative response scales (Bruine de Bruin, Fischhoff, Millstein, &

Halpern-Felsher, 2000). Specifically, less numerate individuals are more likely to use the response of "50" to reflect uncertainty (e.g., "a 50–50 chance"), rather than as an expression of a numerical probability. Although not all uses of the 50% response reflect uncertainty, it was reasoned that participants who gave a greater overall proportion of "50%" responses would be more likely to be using the scale in this manner. Participants' use of the "50%" response was assessed by summing the number of "50%" responses across all nine non-sex-risk judgments. Scores could range from 0 to 9; the sample range for scores was 0 to 9 ($M = .69$, $SD = 1.2$).

Numeracy was also measured by assessing participants' skill in calculating percentages. Six items asked respondents to judge the probability of winning (and not winning) in a raffle, using any percentage from 0% to 100%. Six additional items asked respondents to assess whom, out of a pair of people, had the greater chance of experiencing a particular outcome. In these latter questions, three used a raffle scenario and three dealt with alcohol use and injury. All 12 questions had a correct answer, and participants were provided with sufficient information to judge the probability accurately. Scores, representing the number of correct responses, could range from 0 to 12; the sample range for scores was 0 to 11 ($M = 5.1$, $SD = 2.6$). The relatively low sample mean reflects the stringent scoring criterion used. Because only correct responses were counted, respondents who gave relatively accurate responses (e.g., estimating 98% rather than 99%) were considered no more numerate than respondents who gave wildly inaccurate responses. As such, this assessment of numeracy is a very conservative one.

Lexical expressions of magnitude. After providing percentage estimates of risk for five negative outcomes (tidal wave, minor jogging-related injury, alcohol-related illness, alcohol-related accident, STD), participants were asked to judge the magnitude of the risk on a 5-point scale ranging from "very small" to "very big." These assessments were introduced at the end of the survey in a subsample of 246 participants (78 adolescents, 25 young adults). Those who completed the supplemental measure did not differ from other participants on age, gender, parents' level of education, or on their responses to the 14 core risk-judgment items. A larger percentage of those who completed the additional assessment were White (78% versus 71%), $\chi^2(1, N = 571) = 4.6$, $p < .05$.

Experience with antecedent conditions. Participants were asked if they had ever experienced the antecedent conditions depicted in the risk judgment scenarios. For natural hazards, experience was assessed by asking participants to indicate the number of times they had experienced these

hazards (e.g., "How many times have you been in a lightning storm?"). Conditions that were behavioral in nature were similarly assessed (e.g., "How many times have you had sex without using a condom?"). Response options included: none, 1 time, 2 to 5 times, 6 to 10 times, and more than 10 times.

Data Analysis

Age group differences in mean risk judgments were tested using analysis of variance (ANOVA). When overall age group differences (at $\alpha < .01$) were found, follow-up comparisons between age groups were conducted to identify the source of those differences. All follow-up comparisons used Tukey's B statistic and $\alpha < .05$. Age group analyses were conducted on the full sample as well as selected subgroups in the sample.

Analyses designed to examine age group differences while controlling for the effects of another factor, such as numeracy, were conducted via analysis of covariance (ANCOVA) when the assumption of parallel regression slopes was met. The presence of a significant main effect for age group in these analyses indicates that the effects of age group remained significant, over and above any effects due to the covariate.

RESULTS

Age Group Differences in Risk Judgment

Results from ANOVA showed significant differences between young adults' and adolescents' risk judgments on all 14 items (Table 2). The direction of the differences was invariant; young adults consistently assessed the probability of the negative outcomes as lower than did adolescents. Young adults' assessments were significantly lower than were those of adolescents in each of the three lower age groups, with one exception; for estimates of getting sick following excessive alcohol use, there were no differences between young adults and ninth graders.

Within the adolescent sample, significant age group differences emerged on 11 of the 14 risk judgments (Table 2). Again, the direction of the differences was consistent, with older adolescents assessing a lower probability of negative outcomes than did younger adolescents. Ninth graders assigned lower probabilities in their risk judgments than did seventh graders on 9 of 11 items, and seventh graders assigned lower probabilities than did fifth graders on 4 of 8 items. Examining the results by type of risk, it can be seen that all items concerning natural hazards generated age differences in

TABLE 2
Risk Judgments in Adolescents and Young Adults

Outcome	*Fifth Graders*	*Seventh Graders*	*Ninth Graders*	*Young Adults*	*F Value*	*p*[a]
Die in hurricane	50.0 ± 31.3 (2.8)	38.6 ± 26.5 (2.2)	27.9 ± 25.4 (2.0)	10.0 ± 16.3 (1.4)	61.5	.000
Die in lightning storm	26.3 ± 27.2 (2.5)	18.5 ± 21.3 (1.8)	13.4 ± 18.3 (1.5)	6.4 ± 14.6 (1.2)	22.1[b]	.000
Die in tornado	58.5 ± 32.1 (2.9)	46.7 ± 29.2 (2.4)	33.6 ± 28.5 (2.3)	14.3 ± 21.7 (1.8)	62.2	.000
Die in earthquake	42.2 ± 30.4 (2.8)	32.2 ± 24.8 (2.1)	20.8 ± 20.6 (1.6)	8.9 ± 14.0 (1.2)	53.4	.000
Minor jogging injury	33.2 ± 29.6 (2.7)	28.7 ± 26.2 (2.2)	20.9 ± 22.0 (1.7)	8.4 ± 11.6 (1.0)	30.2[c]	.000
Serious jogging injury	18.3 ± 20.1 (1.8)	15.4 ± 16.7 (1.4)	10.5 ± 14.6 (1.2)	3.8 ± 6.6 (.6)	24.2[c]	.000
Get sick from alcohol	79.0 ± 26.5 (2.4)	79.1 ± 24.40 (2.0)	65.1 ± 33.6 (2.7)	58.7 ± 39.6 (3.3)	14.5[c,d]	.000
Driver in alcohol-related accident	65.8 ± 32.4 (2.9)	71.1 ± 26.1 (2.2)	65.1 ± 30.9 (2.5)	49.2 ± 33.6 (2.8)	13.6[e]	.000
Passenger in alcohol-related accident	82.4 ± 21.2 (1.9)	79.8 ± 19.8 (1.6)	73.9 ± 24.5 (2.0)	50.8 ± 32.6 (2.7)	45.9[b,c]	.000
Pregnancy	N.A.[f]	57.6 ± 27.0 (2.2)	57.4 ± 28.0 (2.2)	28.7 ± 23.5 (2.0)	58.3[e]	.000
Get STD	N.A.[f]	48.5 ± 24.6 (2.0)	41.4 ± 27.2 (2.2)	15.4 ± 20.4 (1.7)	74.4[e]	.000
Get HIV/AIDS	N.A.[f]	44.8 ± 26.6 (2.2)	33.2 ± 28.2 (2.2)	10.8 ± 19.4 (1.6)	68.1	.000
Get STD (infected partner)	N.A.[f]	80.7 ± 19.5 (1.6)	82.6 ± 21.5 (1.7)	65.7 ± 28.5 (2.4)	22.8[e]	.000
Get HIV/AIDS (infected partner)	N.A.[f]	65.6 ± 26.2 (2.2)	52.7 ± 32.1 (2.6)	34.4 ± 32.8 (2.7)	38.00	.000

Note. Values represent mean percentage (probability of harm) ± *SD* (*SE*). STD = sexually transmitted disease; N.A. = not applicable.

[a] Test for significance of overall group differences.

[b] Differences between seventh and ninth graders were not significant.

[c] Differences between fifth and seventh graders were not significant.

[d] Differences between ninth graders and adults were not significant.

[e] No significant differences within the adolescent sample.

[f] Fifth graders were not asked about sexual behavior.

the adolescent sample, as did the items concerning jogging. On risk judgments concerning outcomes related to alcohol use and sexual behavior (less neutral behavioral risks), age differences among adolescents appeared on 5 of 8 items.

We also tested for age group differences in risk judgments within subgroups of the sample defined by gender, race/ethnicity, and parental education level. The same general patterns of age group differences emerged for males and females, Whites and non-Whites, and participants whose parents had different levels of education. The pattern of decreasing risk judgments with age was found in 134 (95.7%) of the 140 comparisons involved in these follow-up analyses (14 risk judgments in each of 10 subgroups); 124 (88.5%) of the differences noted were statistically significant.

Responses to items that elicited lexical expressions of magnitude yielded similar findings. Significant age group differences emerged on four of the five items, with the pattern of findings similar to, but weaker than, those reported for the percentage risk judgments. No age group differences were found on the alcohol-related accident item.

Analyses Controlling for Numeracy

Age group differences were found in participants use of "50" responses, $F(3, 573) = 5.1$, $p = .002$, with significantly higher rates in adolescents (fifth grade, $M = .75$, $SD = 1.2$; seventh grade, $M = .86$, $SD = 1.4$; ninth grade, $M = .78$, $SD = 1.2$) than in young adults ($M = .37$, $SD = .8$).

Skills at calculating percentages also varied by age group, $F(3, 548) = 33.1$, $p < .001$. Skills were lowest in fifth graders ($M = 3.5$, $SD = 2.6$), and significantly higher in each subsequent age cohort (seventh grade, $M = 4.6$, $SD = 2.7$; ninth grade, $M = 5.7$, $SD = 2.3$; young adult, $M = 6.2$, $SD = 1.9$). Differences between ninth graders and young adults were not significant.

To assess whether the observed age differences in risk judgment were due to differences in numeracy, an ANCOVA was conducted for each risk judgment, with the two measures of numeracy used as covariates. After correcting for numeracy, age group differences in risk judgment remained significant for all 14 risk judgments (Table 3). Age group effects accounted for between 5% and 23% of the variance in risk judgments. The direction of the differences was invariant; adolescents gave significantly higher assessments of risk than did young adults. Within the adolescent sample, significant age group differences emerged on 11 of the 14 risk judgments, with older adolescents consistently assessing a lower probability of negative outcomes than did younger adolescents.

TABLE 3
Numeracy-Adjusted Risk Judgments in Adolescents and Young Adults

Outcome	*Fifth Graders*	*Seventh Graders*	*Ninth Graders*	*Young Adults*	*F Value*	p^a	$\eta^{2\,b}$
Die in hurricane	47.8	37.8	27.6	12.7	42.6[c,d]	.000	.19
Die in lightning storm	22.9	17.2	14.1	9.5	9.1[c,d]	.000	.05
Die in tornado	55.6	46.3	33.6	17.1	41.9[c,d]	.000	.19
Die in earthquake[e]	41.4	32.3	21.5	9.6	40.4[c,d]	.000	.18
Minor jogging injury	31.5	27.8	21.4	10.8	18.5[c,d]	.000	.09
Serious jogging injury	16.4	14.6	10.9	6.2	11.2[c,d]	.000	.06
Get sick from alcohol	78.6	78.7	66.2	58.7	11.3[c,d]	.000	.06
Driver in alcohol-related accident	66.9	71.2	66.4	48.5	14.1[c]	.000	.07
Passenger in alcohol-related accident	82.2	79.9	75.7	51.1	41.9[c,d]	.000	.19
Pregnancy[f]	N.A.[g]	57.6	57.4	28.6	56.4[c]	.000	.20
Get STD	N.A.[g]	48.0	41.2	15.8	64.6[c,d]	.000	.23
Get HIV/AIDS	N.A.[g]	44.1	32.7	11.5	57.8[c,d]	.000	.21
Get STD (infected partner)	N.A.[g]	80.5	83.9	65.7	23.7[c]	.000	.10
Get HIV/AIDS (infected partner)	N.A.[g]	64.9	53.5	35.9	30.5[c,d]	.000	.13

Note. Values represent mean percentages (probability of harm). STD = sexually transmitted disease; N.A. = not applicable.

[a] Test for significance of overall group differences.

[b] Size of age group effects, controlling for numeracy.

[c] Significant age group differences between adolescents and young adults.

[d] Significant age group differences among adolescents.

[e] Means adjusted for numeric skill only.

[f] Means adjusted for uncertainty only.

[g] Fifth graders were not asked about sexual behavior.

Analyses Controlling for Numeracy and Behavioral Experience

Perceptions of risk have been found to be lower among people who engage in risk behavior (Benthin, Slovic, & Severson, 1993; Halpern-Felsher et al., 2001; Urberg & Robbins, 1984). In the present sample, as well as in other published reports (Centers for Disease Control and Prevention, 1998), engagement in risky behaviors is greater among older adolescents. By virtue of having lived longer, older individuals are also more likely to have experienced natural hazards. It is thus important to assess whether the observed age group differences in risk judgment are due to differences in participants' level of behavioral and/or natural hazard experience.

A third set of ANCOVA analyses were conducted to determine whether the observed age-group differences would remain after controlling for both skill and behavioral experience. Age group differences remained

TABLE 4
Numeracy- and Experience-Adjusted Risk Judgments in Adolescents and Young Adults

Outcome	*Fifth Graders*	*Seventh Graders*	*Ninth Graders*	*Young Adults*	*F Value*	p^a	$\eta^{2\,b}$
Die in hurricane	47.8	37.6	27.4	12.3	43.6[c,d]	.000	.20
Die in lightning storm	21.8	17.4	14.0	10.0	7.5[c,d]	.000	.04
Die in tornado	55.5	46.5	33.5	17.0	42.0[c,d]	.000	.19
Die in earthquake[e]	40.6	32.5	21.7	10.0	36.6[c,d]	.000	.17
Minor jogging injury	31.3	27.4	21.5	10.8	17.9[d]	.000	.02
Serious jogging injury	16.3	14.1	10.9	6.1	10.8[c]	.000	.06
Driver in alcohol-related accident	64.0	67.7	64.3	60.0	2.2	*ns*	.00
Passenger in alcohol-related accident	80.5	78.5	75.4	54.9	23.9[c,d]	.000	.12
Pregnancy[f]	N.A.[g]	56.8	56.9	29.4	22.6[c]	.000	.09
Get STD	N.A.[g]	45.1	38.6	21.3	16.1[c]	.000	.07
Get HIV/AIDS	N.A.[g]	41.8	30.4	15.8	19.3[c,d]	.000	.08
Get STD (infected partner)	N.A.[g]	78.3	82.2	69.6	5.5[c]	.004	.03
Get HIV/AIDS (infected partner)	N.A.[g]	64.5	53.6	36.6	14.6[c,d]	.000	.07

Note. Values represent mean percentages (probability of harm). STD = sexually transmitted disease; N.A. = not applicable.

[a] Test for significance of overall group differences.

[b] Size of age group effects, controlling for numeracy and experience.

[c] Significant age group differences between adolescents and young adults.

[d] Significant age group differences among adolescents.

[e] Means adjusted for numeric skill and experience.

[f] Means adjusted for uncertainty and experience.

[g] Fifth graders were not asked about sexual behavior.

significant in all but one of these analyses, accounting for between 2% and 20% of the variance in risk judgments (Table 4). The direction of the differences showed the same patterns as in earlier analyses. Adolescents' risk judgments were significantly higher than were those of young adults for all comparisons. Within the adolescent sample, significant age group differences emerged on 8 of the 13 risk judgments, with older adolescents consistently assessing a lower probability of negative outcomes than did younger adolescents.

Accuracy of Risk Judgments

If respondents were accurately assessing the probability of experiencing each outcome, the distributions for 12 of the outcomes would be highly

skewed in the positive direction, because the actual probabilities of occurrence were low. Using this criteria, young adults showed significantly greater accuracy than did adolescents, $\chi^2(1, N = 577) = 5.6, p < .05$; young adults' assessments showed a positive skew (of .6 or greater) on 83% of the relevant distributions, compared with positive skews on 58%, 33%, and 38% of the distributions of ninth, seventh, and fifth graders, respectively.

For a limited number of risks, it was possible to also estimate accuracy by comparing participants' estimates with actuarial data. The hurricane scenario asked participants to judge the risk that they would die if they were in Florida when a strong hurricane hit. One of the worse hurricanes in recent history was Hurricane Andrew, which struck southeast Florida in 1992 and caused 61 deaths. Given the approximate population at the time (~3.2 million in the Miami–Fort Lauderdale consolidated metropolitan statistical area [CMSA]), the risk of dying in the storm was .00002%. Most adolescents (84.6% of fifth graders, 78.9% of seventh graders, and 59.70% of ninth graders) believed the risk was 10% or greater, compared with 22% of young adults, $\chi^2(3, N = 572) = 140.8, p < .001$. Similar results were found for the earthquake scenario. For residents of the San Francisco–Oakland–San Jose CMSA, the risk of dying in the 1989 Loma Prieta earthquake was .00001%. Again, adolescents were more likely to overestimate these risks than were young adults, $\chi^2(3, N = 570) = 105, p < .0001$, with estimates of 10% or greater risk provided by a majority of adolescents (77% of fifth graders, 72.6% of seventh graders, and 50.3% of ninth graders) and 22% of young adults. Another example can be provided with HIV risks. The risk of female-to-male transmission of HIV following a single act of unprotected intercourse with an HIV-infected partner is less than 1% (Haverkos & Battjes, 1992; Mastro, Satten, Taweesak, Sangkharomya, & Longini, 1994). Again, age differences emerged, $\chi^2(2, N = 189) = 48.8, p < .0001$, with a large majority of male adolescents believing their risk to be 10% or greater (97.2% of seventh graders and 77.8% of ninth graders), compared with 46.3% of young adult males.

Inaccuracy was also evident for the higher probability risks and showed the same age trends. Among adolescents, the reported prevalence of the most common STDs, *Neisseria gonorrhoeae* (GC) and *Chlamydia trachomatis*, is between 10% to 20% (Centers for Disease Control and Prevention, 1994). However, most adolescent participants believed that the risk of acquiring an STD with partners of unknown infection status was higher than 20% (82.2% of seventh graders and 66.9% of ninth graders), compared with 21.7% of young adults, $\chi^2(2, N = 190) = 117.2, p < .0001$. Participants also frequently overestimated the risk of STD transmission when the partner was known to be infected. The risk of female-to-male transmission of GC following a single unprotected act of intercourse is 20%, yet a majority

of males in all age groups (95.8% of seventh graders, 90.6% of ninth graders, and 72.2% of young adults) estimated the risk as 30% or greater, $\chi^2(2, N = 189) = 16.3, p < .0005$.

Perceptions of Invulnerability

Risk estimates of 0% reflect beliefs that one faces no risk at all; that is, that one is (absolutely) invulnerable. Participants were considered to show evidence of perceived invulnerability if they responded 0% to any of the 14 risk judgments. (These analyses excluded fifth graders, who did not complete the sex-related items.) Age group differences were found, $\chi^2(2, N = 433) = 9.3, p = .01$, with perceptions of invulnerability seen in 9.9% of seventh graders, 17.8% of ninth graders, and 23.6% of young adults. A significantly greater proportion of young adults demonstrated perceptions of invulnerability (23.6%) than did adolescents (14.0%), $\chi^2(1, N = 433) = 6.1, p < .05$.

Because many of the risks examined were low-probability events, estimates of 0% risk may be more accurate than estimates of 1%. For this reason perceptions of absolute invulnerability were also examined using a subset of four higher probability risks: getting sick from excessive alcohol use, getting an STD, experiencing (or causing) pregnancy, and getting an STD from an infected partner. Across the four items, perceptions of absolute invulnerability were evident in less than 1% of seventh graders, 8.1% of 9th graders, and 14.6% of young adults, $\chi^2(2, N = 449) = 19.8, p < .001$.

To examine the effects of age while controlling for numeracy, hierarchical logistic regression analysis was used. This analysis indicated that the age group differences remained after controlling for numeracy, with a significantly greater proportion of young adults demonstrating perceptions of invulnerability than did adolescents, χ^2 increment $(1, N = 534) = 4.3, p < .05$.

DISCUSSION

The results of this study support a growing body of research that challenges conventional wisdom concerning age differences in perceptions of risk and vulnerability. The contention that adolescents, by virtue of their developmental status, view themselves as invulnerable to harm and underestimate risks is not supported by the present study's data. Adolescents were less likely than were adults to see themselves as invulnerable, and only a small minority of adolescents evidenced such perceptions. In

fact, the rates of invulnerability observed were very similar to those reported by Quadrel et al. (1993). Moreover, individuals' perceptions about the magnitude of their personal risk for experiencing negative outcomes showed an inverse relation to age; younger adolescents perceived greater risk than did older adolescents, and adolescents perceived greater risk than did young adults. These patterns of age differences were robust and consistent across subgroups of the sample defined by gender, race, and parental education, as well as for different types of risks. They persisted even when controlling for other factors associated with risk judgments and/or known to vary by age, such as numerical skill and behavioral experience.

Theories of adolescent egocentrism hypothesize a heightened sense of invulnerability among early adolescents, which decreases as adolescents mature. Delays in ego development and social cognition could prolong personal fable ideation into early adulthood (Lapsley, 1993), but a more typical expectation would be to see decreases in perceived invulnerability occurring around the age of 14, and continuing through early adulthood. Because this study did not sample older adolescents it is not possible to explicitly test theoretical predictions concerning perceptions of risk early and late in adolescence. Nevertheless, it seems reasonable to expect that older adolescents' perceptions of risk would have fallen somewhere between those of the young adolescents and young adults in the sample—a finding that would conflict with current thinking about age differences. The idea that perceptions of invulnerability in older adolescents would be lower than those of both early adolescents and young adults seems far less plausible.

It is even more difficult to reconcile the differences found between adolescents and young adults with theoretical expectations. Even if the young adult sample was considered to be a relatively immature or delayed one, given that they had not yet taken on responsibilities such as marriage and childrearing, it is hard to imagine that in the aggregate they were less mature than were the early adolescents. Additionally, if working status is considered to be an indicator of greater maturity and the adult sample is limited to include only those who were working, the results indicate that the adolescent–adult differences previously described remained significant, robust, and in the opposite direction predicted by current theory (data not shown).

Research on the development of information processing and metacognitive skills, along with knowledge about changes in adolescents' social environments, could help to explain these findings. Millstein and Halpern-Felsher (2001) proposed that younger adolescents are likely to believe that engaging in risky behaviors entails significant risk because this is what they have been taught. With maturation and increased exposure to

peer risk behavior, adolescents are able to observe that most experiences with risky behaviors do not lead to negative outcomes. Coupled with metacognitive skills that allow them to consider the possibility that a contingency is false (Kuhn et al., 1988), the result may be perceptions of lowered risk.

Ultimately, the interpretation and implications of the present study's findings will depend on the meanings ascribed to participants' risk judgments. If the risk judgments are believed to reflect individuals' knowledge about actual risk status, the results point to less realistic risk assessment among adolescents. If they are also considered to be measures of competence in judging risk, then it can be concluded that adolescents were less competent than were young adults, although neither group performed exceptionally well. This is consistent with studies that have found little correspondence between individuals' probability assessments and actual risks of occurrence (Slovic, Fischhoff, & Lichenstein, 1987; van der Plight, 1998).

Alternatively, participants' judgments could be considered to be expressions of their feelings of vulnerability. If this is the case, the results point to a heightened sense of vulnerability among adolescents, compared with young adults, across a range of different risks. Current theoretical perspectives as well as legal statutes recognize that maturity and competence in judging risks involves the ability to recognize one's vulnerability. However, the distinction between mature perceptions of vulnerability and those that could be considered excessive has not been well articulated.

To the degree that risk judgments are viewed as multidimensional and as having cognitive and affective components, both of these interpretations may have some validity. If so, it raises difficult questions about how best to intervene with youth. Most of the participants in this study, including the young adults, significantly overestimated risks. Few people would suggest, however, that youth be provided with information about the magnitude of the actual risks, because doing so could lead to a minimization of their importance. On the other hand, if young people already feel a sense of heightened vulnerability, continuing to emphasize the likelihood of negative outcomes seems counterproductive. Such an emphasis will eventually conflict with adolescents' own experiences, as they become aware of the reality that most experimentation with risky behaviors does not lead to negative outcomes. Fischhoff et al. (2000) also suggest the interesting notion that perhaps adolescents take risks not because of a feeling that they will not die (i.e., perceived invulnerability), but because of a feeling that they are not going to live (i.e., perceived vulnerability).

Perhaps a solution lies somewhere in the realm of finding ways to translate small probabilities into real possibilities, without raising anxiety to unproductive levels. Programs that attempt to personalize and make vivid the reality of negative outcomes, such as those that expose adolescents to individuals who have AIDS, emphasize the meaning and impact of the outcomes rather than the probability of their occurrence. A more challenging but potentially influential approach would be to create opportunities for youth that they would find highly desirable, and that are simultaneously incompatible with risky behavior.

A number of study limitations warrant mention. First, these findings, although suggestive of developmental differences in risk judgment, are based on cross-sectional data. It is therefore possible that, even in this relatively homogeneous sample, the age groups differed in unknown ways or that cohort effects were operating. Determining whether the age differences observed were developmentally based will require longitudinal studies that examine changes within participants over time. Second, the generalizability of the findings is limited by the homogeneous nature of the sample; most participants were White, middle-class individuals who reported relatively low rates of risky behavior. As such, it is not possible to know whether the patterns of age group differences seen in this sample would emerge in other populations. Although similar age patterns were found in subgroups of the sample defined by gender, race/ethnicity, parental education (data not shown), and experience, these results can only be viewed as suggestive, given the small sample sizes involved. For example, only by aggregating all of the racial/ethnic minority groups into one "non-White" group was it possible to compare age-related patterns as a function of race/ethnicity. Studies using larger samples of racial/ethnic minority groups are needed to determine whether patterns of lower risk judgments in older individuals are also evident in these groups.

A third limitation concerns the measurement of perceptions of risk and vulnerability. There are many different ways to conceptualize and measure perceptions of risk and vulnerability (Millstein & Halpern-Felsher, 2001). The present study used magnitude (probability) assessments of risk, both because of their face validity and because they yield a qualitative, ratio-level scale for measuring individuals' predictions concerning uncertain outcomes. Little is known, however, about the meaning that adolescents attribute to different percentage estimates, and analyses controlling for numeracy do not address such potential differences. The degree to which percentage estimates tap into more affective dimensions of risk perception, and perhaps perceptions of invulnerability as well, is unknown.

Additionally, this study did not measure the personal fable construct because interest was limited to only one of its numerous manifestations

(perceived invulnerability), and because of the unsatisfactory performance of existing measurement tools vis-à-vis age-related changes (Lapsley et al., 1989; Vartanian, 2000). Finally, the findings of the current study, although compelling, speak only to one aspect of adolescents' and young adults' judgments of risk. They do not address the process by which risk judgments are made, how risk judgments influence decision making, or why risk judgments show these decreases with age. These are important questions for future studies to consider.

Society holds contradictory views of adolescents' reasoning capabilities (Moshman, 1993). Although the present research, as well as the research of other investigators, does not support the longstanding and popular image of adolescent invulnerability and minimization of risks, neither does it support the idea that adolescents and adults judge risks equally. The reader is cautioned against interpreting the present findings as a wholehearted endorsement of the notion that adolescents and adults are equally competent in judging risk. Future studies will be needed to resolve the inconsistent views of adolescents' competence. Given the far-reaching implications of this resolution for theory, programs, and policies related to adolescents, such research is crucial.

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APPENDIX

Prior to making personal risk judgments, participants were given detailed instructions and examples for using the percentage scale. They were then asked to imagine various situations, and to make risk judgments for similar others. For example, a ninth-grade girl completing the questionnaire would have been asked to

imagine the following situation: Sally is a ninth-grade girl. She is sleeping at home when a strong earthquake strikes. What is the chance that Sally will die in the earthquake?

The introduction for the section on personal risk judgments (the focus of this article) read as follows: In this section we ask you to imagine YOURSELF in similar situations. You personally might never be in these situations. But try to estimate the chance that these things would happen to YOU if you were in these situations, by using any number from 0% to 100%.

1. Imagine that you are visiting a relative who lives in Florida. You are asleep at your relative's house when a strong hurricane strikes. What is the chance that you will die in the hurricane?
2. Imagine that you are at a picnic when a lightning storm strikes. What is the chance that you will die in the lightning storm?
3. Imagine that you are at a picnic when a tornado strikes. What is the chance that you will die in the tornado?
4. Imagine that you are sleeping at home when a strong earthquake strikes. What is the chance that you will die in the earthquake?
5. Imagine that you are at a party. You stay at the party for 3 hours. During the party you have 6 bottles of beer. What is the chance that you will get sick from the beer and throw up?
6. Now imagine that you leave the party to go home. It will take you 15 minutes to get home. You ride your bicycle home alone. What is the chance that you will get into an accident on the way home?
7. Now imagine that instead of going home alone, someone drives you home. The person who drives you home also had 6 bottles of beer at the party. What is the chance that the two of you will get into an accident on the way home?
8. Imagine that you are in love with a guy. You and your boyfriend have had sex together a number of times before. One night, you and your boyfriend have sex 1 time and do not use a condom. What is the chance that you will get a sexually transmitted disease (STD)?
9. What is the chance that you will get HIV / AIDS?
10. Imagine that you weren't using any birth control when the two of you had sex. What is the chance that you will get pregnant?
11. One week later your boyfriend goes to the doctor and finds out that he has a sexually transmitted disease (STD). What is the chance that you will get a sexually transmitted disease (STD)?
12. What is the chance that you will get HIV / AIDS?
13. Imagine that you and a friend run/jog every day. One sunny morning, you and your friend go to a quiet park for a 30-minute run on the jogging path. What is the chance that you will get a serious injury during this run?
14. What is the chance that you will get a minor injury during this run?

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