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Valuing Mortality-Risk Reduction: Using Visual Aids to Improve the Validity of Contingent Valuation

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Abstract

We investigate the validity of contingent valuation (CV) estimates of the value per statistical life (VSL). We test for sensitivity of estimated willingness to pay (WTP) to the magnitude of mortality-risk reduction and for the theoretically predicted proportionality of WTP to risk reduction using alternative visual aids to communicate risk. We find that WTP is sensitive to the magnitude of risk reduction for independent subsamples of respondents presented with each of three alternative visual aids, but not for the subsample presented with no visual aid. Estimated WTP is consistent with proportionality to risk reduction for the subsamples presented with a logarithmic scale or an array of 25,000 dots, but not for the subsample receiving a linear scale. These results suggest that CV can provide valid estimates of WTP for mortality-risk reduction if appropriate methods are used to communicate the risk change to respondents.

Keywords: contingent valuation, VSL, WTP, sensitivity to scope, risk communication, risk ladder

JEL Classification: I1, D6, D8, H4

1. Introduction

The economic approach to valuing reductions in mortality risk requires estimating the rate at which an individual would trade her own money for a small change in her chance of dying in a specified time period. The marginal rate of substitution or "value per statistical life" (VSL) is most often estimated using revealed-preference or contingent-valuation (CV) methods (Viscusi, 1993). Under CV, survey respondents are asked to state their willingness-to-pay (WTP) for a specified hypothetical risk reduction. Revealed-preference methods estimate the tradeoff using information about individuals' choices between jobs, consumer goods, or other alternatives that differ in monetary consequences and risk.

There is concern about the validity of CV estimates, in part because they do not rely on observed behavior. One criterion for judging the validity of CV estimates is their sensitivity to factors that should theoretically influence WTP, such as the respondent's

income and the quantity of the good (Mitchell and Carson, 1989). If estimated WTP is insensitive to the magnitude of the good, it casts doubt on the validity of the estimates (NOAA, 1994; Desvousges, Johnson, and Dunford, 1993; Diamond and Hausman, 1994).

As described in Section 2, economic theory suggests that WTP for a small mortality-risk reduction should be nearly proportionate to the magnitude of the risk reduction. In contrast, most CV studies have estimated WTP values that vary less than proportionately to the risk reduction, and so the derived VSL estimate depends on the (usually arbitrary) choice of risk reduction (Hammitt and Graham, 1999). For example, Jones-Lee, Hammerton, and Philips (1985) estimated mean WTP to reduce the risk of dying in a travel accident by 4/100,000 as £137, yielding a VSL of £3.4 million. Mean WTP for a 75% larger risk reduction (7/100,000) was only 15% greater (£155), yielding a smaller estimated VSL of £2.2 million.[1]

Although it is possible that preferences for mortality-risk reduction are not consistent with the standard economic model, or that CV is incapable of measuring such preferences (Fischhoff and Furby, 1988; Beattie et al., 1998; Kahneman, Ritov, and Schkade, 1999), an alternative explanation for the typically inadequate sensitivity to magnitude is that the small risk changes have not been adequately communicated to survey respondents. There is a wealth of evidence that people have limited appreciation for small probabilities (Baron, 1997a, 1997b; Featherstonhaugh et al., 1997; Fisher, Chestnut, and Violette, 1989a; Frederick and Fischhoff, 1998; Gomez, 1990; Viscusi, 1998). To the extent that respondents do not understand the magnitude of the risk change, their responses are unlikely to accurately represent their preferences. Deficient risk communication may explain why CV estimates of WTP for mortality-risk reduction vary less than proportionately to the magnitude of the reduction. Near-proportionality can be used as a test for adequacy of risk communication and as a necessary (but not sufficient) condition for validity of the WTP estimates (Hammitt, 2000a).

A number of risk communication tools have been developed to assist respondents in comprehending the magnitude of risk reductions. Kunreuther et al. (l978) presented respondents with a table reporting the probabilities of a newborn surviving to various ages (a survival curve). Jones-Lee et al. (1985) used graph paper containing 100,000 squares with the appropriate number blacked out. Mitchell and Carson (1986) and Hammitt (1986, 1990) used "risk ladders" which present the numerical probabilities of dying from various causes on a visual scale. Smith and Desvousges (1987) used a series of pie charts. Hammitt and Graham (1999) used verbal "probability analogies" expressing numerical risks as analogous to the corresponding number of minutes in a year. Despite numerous applications of these devices (e.g., Calman and Royston, 1997; Fisher, McClelland, and Schulze, 1989b; Kaplan, Hammel, and Schimmel, 1985; Moschandreas and Chang, 1994; Weinstein, Sandman, and Hallman, 1994; Sandman, Weinstein, and Miller, 1994), we know of only one study that directly tests the effects of visual aids on WTP responses in a large, general-population sample (Loomis and duVair, 1993).

The purpose of this study is to test whether alternative methods of communicating risk enhance the sensitivity of estimated WTP to the magnitude of risk reduction, and so yield CV estimates that are more consistent with economic theory. We estimate WTP for an automobile-safety device (a side-impact airbag) in four independent subsamples.

Respondents in each subsample are presented with one of three visual aids (a logarithmic scale, a linear scale, and an array of dots) or no visual aid. The airbag is stated to provide an annual risk reduction of 1/10,000 or 0.5/10,000. Each respondent values only one risk reduction, and we evaluate between-respondent differences in WTP as a function of the difference in risk reduction.

We find that WTP is nearly proportionate to the risk change for the subgroups exposed to the dots and the logarithmic risk ladder. In contrast, estimated WTP is insensitive to the magnitude of risk reduction for the group that received no visual aid. The linear risk ladder produced intermediate results. We conclude that the less-than-proportionate relationship between WTP and risk reduction observed in previous CV studies may reflect inadequate risk communication. Because they exhibit the theoretically anticipated near proportionality of WTP to risk reduction, our estimates based on the dots and logarithmic scales are arguably valid measures of economic preferences for risk reduction, whereas those from the other subsamples are not.

The paper is organized as follows. Theoretical background is presented in Section 2 and previous empirical results are reviewed in Section 3. The survey design and methods are described in Section 4. Section 5 presents the empirical models and results, and Section 6 offers concluding observations.

2. Theoretical background

Under minimal assumptions (more is preferred to less and non-satiation), economic theory predicts that WTP should increase with the quantity of the good, but it provides little information about how much WTP should increase. In the special case we consider where the good is a small change in the probability of one's own death, illness or injury within a specified time period, standard theory implies that WTP should be nearly proportionate to the change in probability (Hammitt, 2000a).

The standard model of WTP for a change in mortality risk assumes the individual seeks to maximize her expected state-dependent utility

$$EU(p, y) = (1 - p)u_a(y) + pu_d(y) \tag{1}$$

where p is her probability of dying during a defined period and $u_a(y)$ and $u_d(y)$ are her utilities as a function of income y conditional on surviving and dying in that period, respectively. Differentiating equation (1) yields the standard result

$$VSL = \frac{dy}{dp} = \frac{u_a(y) - u_d(y)}{(1 - p)u'_a(y) + pu'_d(y)}. \tag{2}$$

Assuming survival is preferred to death $[u_a(y) > u_d(y)]$, and the marginal utility of income is non-negative and greater given survival than death $[u'_a(y) > u'_d(y) \geq 0]$, and risk aversion $[u'_a \leq 0, u'_d \leq 0]$, VSL (the marginal rate of substitution between mortality risk and income) increases with p and y (Jones-Lee, 1974; Weinstein et al., 1980; Pratt and Zeckhauser, 1996).

The value of a discrete (non-marginal) reduction in mortality risk can be obtained by integrating VSL with respect to risk between the initial and final risk levels. As an individual buys successive incremental risk reductions, her income and risk decline, reducing her VSL. For the small risk reductions typically valued using CV, however, the effects of changes in p and y should not cause substantial changes in VSL and so cannot explain substantial departures from proportionality between WTP and risk reduction.

First, consider the effect of the change in p. The decrease in p increases the value of the denominator in equation (2) and so reduces VSL. Because $u'_d(y) \geq 0$, the proportional decrease is less than $(1 - p)/(1 - p + \Delta p) = 1/[1 + \Delta p/(1 - p)]$ where Δp is the risk change. For the usual case where the risk reduction to be valued (Δp) is orders of magnitude smaller than the survival probability $(1 - p)$, this effect is negligible.

The effect of a decrease in income y is less certain, but available evidence suggests it is also small. Empirical estimates of the income elasticity of VSL are typically no greater than one (Viscusi, 1993; Liu, Hammitt, and Liu, 1997; Hammitt, 2000b), which implies that the proportional decrease in VSL is no larger than the ratio of WTP to income. In this study, WTP is less than about 1% of mean income and so the effect on VSL should also be less than about 1%.

In short, for the small risk changes of interest, the marginal rate of substitution between income and risk should be nearly constant, and so WTP for a small risk reduction should be well approximated by initial VSL times the change in mortality probability. Near-proportionality appears to be a necessary (but not sufficient) condition for CV estimates of WTP for mortality-risk reduction to be valid measures of economic preferences.

The standard model assumes that individuals maximize the expected utility of income and survival probability. Most alternative models of decision making under risk (e.g., Rank-Dependent Expected Utility, Quiggin, 1982; Cumulative Prospect Theory, Tversky and Kahneman, 1992) evaluate outcomes using a probability-weighting function that is approximately linear for small changes in the probabilities (Machina, 1987), and so these models also imply that WTP is nearly linear for small risk changes (Hammitt, 2000a). An exception is Prospect Theory which admits discontinuities at thresholds where probabilities are rounded to zero and one (Kahneman and Tversky, 1979). Although such thresholds may be invoked *post hoc*, there is no general theory regarding where they occur.

An alternative explanation for departure from proportionality is that respondents are valuing a risk change different than the one stated in the survey instrument, a form of scenario rejection (Mitchell and Carson, 1989). According to Prospective Reference Theory (Viscusi, 1985, 1989), respondents combine personal prior estimates of the effectiveness of the stated intervention with the effectiveness stated in the CV instrument to obtain a posterior estimate of the risk reduction for which they report WTP. Since the posterior estimates are in general between the prior estimates and the values specified in the survey, they vary less than the stated risk reductions, and so reported WTP will vary less than proportionately to the specified risk increments. In this case, CV cannot be used to estimate the rate of substitution between income and risk unless the posterior risk changes can be estimated.

3. Empirical background

In a review of all CV studies estimating the value of a numerically specified change in health risk published since 1980, Hammitt and Graham (1999) found only eight studies that provided sufficient information to evaluate the sensitivity of WTP to risk reduction. Several of these found no variation of WTP in response to risk reductions. Lin and Milon (1995) found that WTP for a reduction in risk of illness from eating oysters was insensitive to the magnitude of risk reduction. In a split sample with a 2.5-fold difference in risk reduction, WTP decreased as risk reduction increased. Similarly, Eom (1994) found little variation in WTP across alternative scenarios for reducing health risks from exposure to pesticide residues on fresh produce.

Smith and Desvousges (1987) used risk circles (pie charts) to elicit WTP valuations where the baseline risk of being exposed to hazardous wastes varied between samples. They found that WTP decreased as stated fatality risk reduction increased. The authors note that poor understanding of the risk context, fear of dying from exposure to hazardous wastes, and temporal differences in the CV format might explain the unexpected results of the study.

Johannesson, Jonsson, and Borgquist (1991) found a positive but non-significant association between individuals' perceived risk reduction and WTP for antihypertensive therapy to reduce risk of cardiovascular disease. In a study that valued reductions in angina pectoris attacks, Kartman, Andersson, and Johannesson (1996) found that WTP increased with the size of the reduction in attacks. The difference was significant in the groups where WTP was elicited using a bidding format but not in those using a single dichotomous-choice format. Similarly, Kidholm (1995) found that in a survey of a Danish population, WTP to reduce the risk of dying in a traffic accident increased with the size of risk reduction after the absolute WTP values were adjusted to reflect differences in distance driven.

Viscusi, Magat, and Huber (1987) asked respondents to value reductions in several non-fatal injuries from an initial risk of 15/10,000 by 5, 10, and 15/10,000. They found that the incremental WTP to reduce risk by 5/10,000 varied widely. WTP for the second increment (from 10/10,000 to 5/10,000) was one-quarter to one-third as large as WTP for the initial increment (from 15/10,000 to 10/10,000) and WTP for the third increment (from 5/10,000 to zero) was four to ten times larger than WTP for the second increment. The smaller WTP for the second increment is consistent with inadequate sensitivity to magnitude. The larger-than-proportionate difference between the second and third increments was attributed to the existence of a certainty premium for eliminating the risks, which is also inconsistent with the standard economic model (equation (2)).

Jones-Lee et al. (1985) used an array of 100,000 squares to communicate reductions in travel-fatality risks. As noted in Section 1, they found that mean WTP to reduce fatality risk by 7/100,000 was only 15% greater than WTP to reduce fatality risk by 4/100,000. Using a similar visual aid, Jones-Lee, Loomes, and Philips (1995) found that WTP to reduce the risk of suffering a specified serious injury in an automobile crash by 12/100,000 was only about 20% larger than WTP to reduce the same risk by 4/100,000.

Only a few studies have tested for between-group sensitivity to magnitude using alternative risk-communication devices. Muller and Reutzel (l984) compared WTP for reductions in the risk of fatality, conditional on involvement in an automobile crash, when the risk reduction was characterized using a base of 100 and a base of 10,000. For both expressions of risk reduction, respondents (77 college students) were willing to pay more for larger risk reductions, although the differences were not statistically significant. For twice as large a benefit, WTP was 79% higher and 47% higher in the groups where the risks were expressed as chances out of 100 and out of 10,000, respectively.

Hammitt and Graham (1999) tested the effect of a verbal probability analogy on WTP for automobile safety. In the exposed group, each numerical probability was accompanied by a corresponding analogy to the number of minutes in a year (e.g., a 20/100,000 annual risk is compared with 105 minutes in a year). The authors found that the estimated sensitivity to magnitude was independent of whether respondents were exposed to probability analogies and that estimates of WTP were less than proportionate to the risk increment.

Only Loomis and duVair (1993) have previously tested the effect of different visual aids on WTP. Within sample, they found that the absolute level of risk reduction (a 25%, 50% or 75% reduction) was statistically significantly related to WTP for the groups that were exposed to a risk ladder or a pie chart (at 10% and 5%, respectively), although WTP was less than proportionate to the level of risk reduction.[2]

To our knowledge, we are the first to conduct a between-sample comparison of the effect of alternative visual aids on sensitivity of WTP to magnitude of risk reduction.

4. Survey design and methods

The survey questions were adapted from previous work by Hammitt and Graham (1999). Question wording, visual aids, and the mode of administration were refined through focus groups and pilot testing. Data were collected using a mixed-mode phone-mail-phone survey. A random sample of residents of the continental United States aged 18 years and older was recruited by random-digit dialing. The first interview collected socio-demographic data including age, sex, race, income, marital status, number of children less than 18 years old living at home, and employment status. Respondents were mailed a packet containing the appropriate visual aid together with a personally addressed cover letter (with original signatures) and a $5 gratuity. WTP was elicited during the second interview, conducted within two weeks of receipt of the visual aids. If the respondent could not be reached after six attempts, we sent a follow-up letter that asked the respondent to call a toll-free number to complete the survey.

The CV interview, which took 20 to 25 minutes to complete, contained a section that asked respondents about their WTP to reduce annual mortality risk associated with automobile crashes. Respondents were told their initial and final annual risk levels if they chose to purchase an optional side-impact airbag on the next vehicle they purchase. The side-impact airbag was described as similar to a frontal-impact airbag except that it protects drivers in a side-impact rather than in a head-on crash. Two versions of the

survey were prepared: one in which the initial annual risk of dying in a motor-vehicle crash was 2.5/10,000, and the other in which it was 2.0/10,000. For both versions, the purchase of a side-impact air bag would reduce the annual risk of dying in a motor vehicle crash to 1.5/10,000.

WTP was elicited using a double-bounded dichotomous-choice question format (Hanemann, Loomis, and Kanninen, 1991) with an increase in annual car payments over a five year period as the payment vehicle. Respondents were randomly assigned a first bid amount with predetermined lower and higher follow-up bids used if the respondent answered "no" or "yes" to the initial bid. The bid vectors were: $\langle \$50, \$25, \$100 \rangle$, $\langle \$100, \$50, \$200 \rangle$, and $\langle \$200, \$100, \$400 \rangle$. A fourth bid vector, $\langle \$400, \$200, \$800 \rangle$, was added after a preliminary analysis of 10% of our sample suggested that our bids had been set too low to capture the upper part of the WTP distribution.[3]

The bid vectors permit estimation of a wide range of VSL. A respondent who says she would not purchase the airbag offering the larger risk reduction at the smallest follow-up bid reveals a VSL less than $250,000. A respondent who says she would purchase the airbag offering the smaller risk reduction at the largest follow-up bid reveals a VSL greater than $16 million.

In addition to the CV questions, the survey included a range of attitudinal questions related to automobile safety and knowledge about airbags. CV practitioners have often identified "familiarity" with the good as essential for reliability (Mitchell and Carson, 1989). We asked participants if they had a frontal-impact airbag in any of the vehicles in their household, how effective they thought airbags were in preventing automobile fatalities, and what they thought their personal mortality risk was compared with the stated baseline risk. The survey also included a question that prompted participants to be cognizant of their budget constraints, asking them how confident they were in their response about WTP, given their household income and other expenses. In a sensitivity analysis, we compare WTP for those persons expressing the highest level of confidence with all others. Previous studies have found that estimated WTP is more consistent with theory for respondents who reported greater confidence in their answers (e.g., Johannesson et al., 1993; Li and Mattson, 1995; Ready, Whitehead, and Blomquist, 1995; Hammitt and Graham, 1999).

Eight versions of the visual-aid packet were randomly assigned to study participants; they correspond to the two baseline levels of annual mortality risk associated with automobile crashes (2.5 and 2.0 in 10,000, respectively) and four visual-aid groups (a linear scale, a logarithmic scale, an array of dots, and a group receiving no visual aid).

To develop the communication devices, we drew on previous visual aids developed by Jones-Lee et al. (1985), Hammitt (1986, 1990), and comments from a focus group conducted in July 1998. Study participants were randomized to one of the three visual-aid groups or into a fourth group, which was not provided a visual aid.

Two of the visual aids are multi-colored logarithmic and linear[4] scales (black and white copies are provided in the Appendix). On these risk ladders, each rung represents a progressively higher annual risk. Several annual fatality risks are included to enhance respondent understanding of the small probabilities. Examples include the annual probability of being fatally struck by lightning (2 in 10 million) and of dying in a fire

(1.5 in 100,000). The comparative risks were chosen because pretesting suggested that the study population was familiar with them. The logarithmic and linear scales also include "community analogies" adapted from Calman and Royston (1997). For example, a 1 in 10,000 risk is characterized as implying one expected death per year in a typical small town, and a 1 in 1 million risk as implying one expected death per year in a typical city. Both risk scales show the absolute reduction in risk level as movement down the rungs of the ladder; risk levels with and without the airbag are marked with blue stars.

The third visual aid is an 11" × 17" black and white display of 25,000 dots divided into 10 by 10 groups. A brief explanatory page provided several analogies to convey the magnitude of 25,000 in other contexts For example, 25,000 feet is the height of the highest campsite in the world (on Mt. Everest), and 25,000 days is the time until a newborn reaches age 70 years.

5. Statistical model and results

We conduct "weak" and "strong" tests of sensitivity to magnitude of risk reduction. Weak sensitivity is satisfied if WTP is sensitive to the magnitude of the risk reduction, and strong sensitivity is satisfied if WTP is proportional to the magnitude of the risk reduction.

We estimate WTP using the maximum-likelihood method for a standard double-bounded or interval-data model (Alberini, 1995). The implicit assumption is that one underlying WTP value drives the responses to both dichotomous-choice questions. If this is true, the second question provides a tighter interval around the true WTP value and the maximum-likelihood optimization model is appropriate. We test the sensitivity of our results to follow-up effects such as yea-saying, starting-point bias, and heteroscedasticity between responses (Alberini, Kanninen, and Carson, 1997; Cameron and Quiggin, 1994; Kanninen, 1995) by estimating an alternative, single-bounded model using only the response to the first question. In addition, we test the effect of alternative distributional assumptions (lognormal and Weibull), with and without socio-demographic and attitudinal variables.

5.1. Empirical results

Data were collected between December 1998 and March 1999. A total of 1,456 participants were initially recruited by telephone and mailed a visual-aid packet. Of these, 69 (4.7%) reported they never received a packet, 29 (2.0%) refused to complete the interview, 33 (2.3%) were unable to complete the survey because of illness, disability, or death, and 221 (15.2%) were unreachable by telephone after several attempts. We present results for 1,104 completed telephone interviews, a 75.8% completion rate.

Table 1 compares sample characteristics for the full sample and for each subsample. Overall, the study population is predominantly white (80%), married (56%), less than 45 years old (57%), and employed full-time (56%). Fewer than half are male (46%) or

Table 1. Sample statistics

Variable	No aid	Linear	Logarithmic	Dots
Sample size (1,104 total)	277	288	264	275
Response rate (%)[a]	77	74	76	76
Male (%)	41	51	48	43
Age[b]	43.0	42.3	42.9	44.4
Income ($1,000)[c]	47.6	46.5	45.4	46.4
Education (years)[d]	14.5	14.6	14.2	14.4
Perceived airbags as "very effective" (%)	42	49	46	42
Perceived risk $\geq$ stated risk (%)	62	59	58	56
Quality of life (1 to 10 scale)	7.5	7.6	7.5	7.5
Employed full-time (%)	59	56	58	51
Married (%)	58	56	52	56
Children <18 living at home (%)	44	37	38	38
White (%)	81	76	83	81

[a]Based on 1,456 participants recruited.
[b]Age provided within the following categories: (18–24), (25–29), (30–34), (35–39), (40–44), (45–49), (50–54), (55–59), (60–64), (65–69), and (70+). Age 70 was used for the upper bound.
[c]Household income (in $1000) within the following categories: (<$15), ($15–$25), ($25–$40), ($40–$50), ($50–$75), ($75–$100), (>$100). $15 and $100 were used for the lower and upper bounds, respectively.
[d]Years of educational attainment, where less than high school = 10; graduated high school = 12; some college = 14; graduated college = 16; and graduate or professional school = 18.

have children less than 18 years old living at home (39%). The full sample has lower-than-average household income ($46,000 compared with $49,000 U.S. median household income in 1997) and higher-than-average educational attainment (14.4 years compared with 13.1 years for the U.S. population in 1998).[5] The subsamples are similar, with no significant differences in means (two-sample t-test, $p < 0.05$). This suggests that any differences in responses are caused by the risk-communication devices.

Nearly 65% of respondents report having a frontal-impact airbag, suggesting familiarity with airbags. Respondents were asked to rate the effectiveness of airbags in preventing death and injury in automobile crashes from very effective (45%) to not at all effective (1%). After participants were provided with the average baseline risk, they were asked to judge their chances of being killed in an automobile crash given their own personal situation. The majority believe their risk to be average (42%) or lower-than-average (41%), with 17% estimating their risk to be higher-than-average.[6]

Table 2 presents the estimated regression equations pooling responses across risk-reduction levels within the linear, logarithmic, dots, and no-aid groups. The regression equations are estimated assuming a lognormal distribution. "Risk change" is a dummy variable equal to one for the subsample presented with the larger risk reduction (1.0/10,000) and zero for the subsample presented with the smaller risk reduction (0.5/10,000). Its coefficient estimates the logarithm of the ratio of WTP for the larger risk reduction to WTP for the smaller risk reduction. If WTP is exactly proportional to

Table 2. Estimated WTP by visual aid, no covariates

Variable	No aid	Linear	Logarithmic	Dots
Constant	5.448***	5.630***	5.333***	5.067***
	(0.141)	(0.145)	(0.145)	(0.141)
Risk change[a]	0.097	0.318	0.503**	0.658***
	(0.198)	(0.202)	(0.198)	(0.209)
N	277	288	264	275
Log-likelihood	−362.96	−357.01	−354.62	−350.55
WTP ratio (from regression)[b]	1.10	1.37	1.65	1.93
Median WTP[c]	$253/$235	$362/$293	$337/$209	$290/$159
95% CI	$193–$331	$278–$472	$257–$441	$221–$382
	$174–$317	$209–$412	$154–$284	$115–$219
WTP ratio (from subsamples)[d]	1.08	1.24	1.61	1.82

Notes: (standard error)

***, **, *statistically significant from 0 at 1%, 5% and 10%, respectively.

[a]Indicator variable = 1 for larger risk reduction and 0 for smaller risk reduction.

[b]Ratio of WTP for larger risk reduction to WTP for smaller risk reduction estimated by the coefficient on "Risk change."

[c]Median WTP for larger and smaller risk reductions estimated from regression using only corresponding subsample.

[d]Ratio of median WTP by subsample.

the two-fold absolute difference in risk reduction, the expected value of the coefficient is $\ln(2) = 0.693$.

Median WTP ranges from $253 (no aid) to $362 (linear) for those presented with the larger risk reduction, and from $159 (dots) to $293 (linear) for those presented with the smaller risk reduction. The hypothesis that WTP is insensitive to the magnitude of risk reduction (the weak test) can be rejected for the dots ($p < 0.01$) and for the logarithmic scale ($p < 0.05$), but not for the linear scale ($p = 0.11$) or no visual aid ($p = 0.62$) subsamples. The hypothesis that WTP is proportional to the risk reduction (the strong test) can be rejected for the group receiving no visual aid ($p < 0.01$) or the linear scale ($p < 0.05$), but not for the dots ($p = 0.43$) or the logarithmic scale ($p = 0.17$).

Table 3 presents similar estimated regression equations by risk-communication device, but including the main socio-demographic and attitudinal covariates of interest: age, sex, household income, educational attainment, perceived effectiveness of airbags, perceived risk (compared with the stated initial risk), and the interaction between perceived airbag effectiveness and perceived risk. Consistent with the hypothesis that mortality-risk reduction is a normal good, income is positively associated with WTP in all subsamples except the group receiving the linear scale, although it is statistically significant in only the groups receiving the dots or no visual aid. Men are estimated to have smaller WTP in all subsamples, but the difference is significant only in the group receiving no visual aid. Age is negatively associated with WTP for all subsamples except the group receiving

Table 3. Estimated WTP by visual aid, with covariates

Variable	No aid	Linear	Logarithmic	Dots
Constant	6.009***	4.993***	5.253***	4.837***
	(0.741)	(0.734)	(0.727)	(0.788)
Risk change[a]	0.062	0.349*	0.429**	0.678***
	(0.195)	(0.196)	(0.191)	(0.206)
Age	−0.015**	−0.005	−0.013*	0.0001
	(0.007)	(0.007)	(0.007)	(0.007)
Male	−0.434**	−0.318	−0.191	−0.249
	(0.206)	(0.198)	(0.193)	(0.210)
Income ($1,000)	0.0096**	−0.00007	0.00005	0.0088**
	(0.004)	(0.004)	(0.004)	(0.004)
Education	−0.034	0.038	0.015	−0.006
	(0.048)	(0.047)	(0.047)	(0.050)
Effective[b]	0.263	0.633**	1.102***	0.078
	(0.317)	(0.309)	(0.298)	(0.309)
Perceived Risk[c]	0.194	0.122	0.292	−0.279
	(0.261)	(0.277)	(0.254)	(0.271)
Effective ∗ Perceived Risk	0.454	0.258	−0.486	0.601
	(0.407)	(0.402)	(0.384)	(0.417)
N	277	288	263	275
Log-likelihood	−351.18	−346.33	−341.14	−344.02
WTP ratio (from regression)[d]	1.06	1.42	1.54	1.97
Median WTP[e]	$244/$233	$365/$287	$321/$210	$303/$164
VSL[f] (millions)	$2.4/$4.7	$3.7/$5.7	$3.2/$4.2	$3.0/$3.3

Notes: (standard error)

***, **, *statistically significant from 0 at 1%, 5% and 10%, respectively. One record was excluded because all socio-demographic variables were missing. 77 missing income values were predicted using a regression of income on gender, age, and years of education.

[a]Indicator variable = 1 for larger risk reduction and 0 for smaller risk reduction.

[b]Indicator variable = 1 for rating of airbags as "Very Effective" and 0 otherwise.

[c]Indicator variable = 1 if perceived risk is greater than or equal to stated risk, 0 otherwise.

[d]Ratio of WTP for larger risk reduction to WTP for smaller risk reduction estimated by the coefficient on "Risk change."

[e]Median WTP for larger and smaller risk reduction predicted for average respondent using regression for corresponding visual aid.

[f]Value per Statistical Life = WTP/mortality-risk reduction.

the array of dots, although significant only in the groups receiving the logarithmic scale or no visual aid. Years of educational attainment is not significant for any subsample.

Perceived airbag effectiveness is positively associated with WTP. It is significant only in the groups receiving a logarithmic or linear scale, but is significant in every subsample when the interaction term between effectiveness and perceived risk is excluded (results not shown). "Perceived Risk" and its interaction term with airbag effectiveness are not significant and show no consistent influence on WTP across subsamples.

For the models including covariates, the hypothesis that WTP is insensitive to the magnitude of risk reduction can be rejected for subsamples receiving the dots ($p < 0.01$),

the logarithmic scale ($p < 0.05$), and the linear scale ($p < 0.08$), but cannot be rejected for the group receiving no visual aid ($p = 0.75$). The hypothesis that WTP is proportional to the risk reduction can be rejected for the group receiving no visual aid ($p < 0.01$), the linear scale ($p < 0.05$) or the logarithmic scale ($p < 0.10$), but not for the group receiving the array of dots ($p = 0.47$).

Because estimated WTP is less than proportionate to the risk reduction, derived VSL is higher for the smaller risk reductions. VSL estimates range from $2.4 million (no aid, larger risk reduction) to $5.7 million (linear, smaller risk reduction). These estimates are consistent with recommended values (Fisher et al., 1989a; Viscusi, 1993).

Table 4 presents a regression equation estimated using the full sample and including indicator variables for the three visual aids and their interactions with the dummy variable indicating magnitude of risk reduction. The coefficients of the socio-demographic variables have the same signs as in Table 3, with all showing significance except years

Table 4. Estimated WTP for full sample, with covariates

Constant	5.360***
	(0.393)
Risk change	0.070
	(0.194)
Male	−0.281***
	(0.100)
Age	−0.008***
	(0.003)
Income ($1,000)	0.004*
	(0.002)
Education	0.0057
	(0.024)
Effective	0.553***
	(0.153)
Perceived Risk	0.078
	(0.133)
Effective ∗ Perceived Risk	0.199
	(0.201)
Linear scale	0.140
	(0.194)
Linear scale ∗ Risk change	0.278
	(0.275)
Logarithmic scale	−0.084
	(0.199)
Logarithmic scale ∗ Risk change	0.364
	(0.278)
Dots	−0.374*
	(0.192)
Dots ∗ Risk change	0.606**
	(0.278)

Notes: (standard error)
***, **, *statistically significant from 0 at 1%, 5% and 10%, respectively.

of educational attainment. The significance of the coefficients on "Dots" and its interaction with the risk change variable suggest that the WTP elicited from persons receiving the array of dots differs from that elicited from persons receiving no visual aid, both in its level and sensitivity to magnitude.[7] The corresponding coefficients for the linear and logarithmic scales are not significant, suggesting no systematic effect of these visual aids compared with no aid.

5.2. Sensitivity analysis

To test the sensitivity of our results to response effects in the double-bounded dichotomous-choice format, we estimate a single-bounded model using only the response to the first dichotomous-choice question. Single-bounded estimates of the models in Table 2 have less power than the double-bounded estimates and allow us to reject the hypothesis that WTP is insensitive to the magnitude of risk reduction only for the group receiving the array of dots ($p < 0.05$). For this subsample, the estimated ratio of WTP for the larger risk reduction to the smaller risk reduction (2.6) suggests a greater-than-proportionate response, but the hypothesis that WTP is proportionate to risk reduction cannot be rejected ($p = 0.72$). As suggested by Hanemann et al. (1991), the single-bounded model yields higher point estimates of WTP (median estimates of \$599 and \$231 for large and small risk reductions, respectively, for the group receiving the array of dots).

Assuming WTP is distributed in accordance with a Weibull rather than a lognormal distribution has little effect on the results. Estimates of the models in Table 2 under this assumption allow rejection of the hypothesis that WTP is insensitive to the magnitude of risk reduction for the dots ($p < 0.05$) and for the logarithmic scale ($p < 0.05$), but not for the linear scale ($p = 0.35$) or no-visual-aid ($p = 0.78$) subsamples. Under the Weibull assumption, we reject proportionality for the linear scale and no-visual-aid subsamples ($p < 0.05$), but not for the groups receiving either the dots or the logarithmic scale.

Pooled over the four risk-communication devices and the two levels of risk reduction, the fraction of respondents reporting each degree of confidence in their WTP responses are: 54.1% very confident, 38.5% somewhat confident, 5.7% not too confident, and 1.1% not at all confident. Separate regressions using the subsample of respondents who felt "very confident" in their response found no difference in sensitivity to magnitude compared with the full samples, in contrast to some previous studies (e.g., Johannesson et al., 1993; Li and Mattson, 1995; Ready et al., 1995; Hammitt and Graham, 1999).

6. Conclusion

Previous CV studies have typically found that WTP is less sensitive to the stated magnitude of risk reduction than standard economic theory would predict. A plausible explanation for this inadequate sensitivity to magnitude is that respondents may not understand the magnitude of the described risk reduction.

We find important differences in the effect of alternative visual aids on sensitivity of estimated WTP to magnitude of mortality-risk reduction. For a subsample of respondents that received no visual aid, there is no statistically significant relationship between WTP and magnitude of risk reduction. In contrast, there is a statistically significant relationship between WTP and risk reduction for each of the three subsamples receiving a visual aid. The magnitude of the response and the significance level differ among the visual aids. The dots yield results that are perfectly consistent with standard economic theory, and the logarithmic scale yields results that are not statistically significantly different from theory. We obtained similar results using an alternative WTP distribution (Weibull). Using a single-bounded model, only the subsample receiving the array of dots exhibits statistically significant sensitivity to magnitude.

Only the estimates using the logarithmic scale and the array of dots are consistent with proportionality between WTP and risk reduction. Given that near proportionality is a necessary (but not sufficient) condition for valid estimates of WTP for small mortality-risk changes, we consider our estimates of VSL using the logarithmic scale and especially the array of dots to be possibly valid, suggesting that the average VSL for automobile-fatality risk in our sample is in the $3 to $4 million range.

Explanations for the differential performance of the visual aids are speculative. The improved performance of the logarithmic and linear risk scales, compared with no visual aid, is consistent with Hsee's (1996) "evaluability hypothesis" which suggests that an attribute that is hard to evaluate independently may be more influential if comparative values are also provided. The superior performance of the dots over the risk scales may arise because the array of dots provides a frequency rather than a probability depiction of risk, which some authors contend is easier to comprehend (Gigerenzer, 1995, 1996). In addition, the dots provide a visual depiction that is linearly related to the risk, which may be more intuitive than the logarithmic scale. Alternatively, the relative simplicity of the dots may be the most important factor. The comparative risks included on the linear and logarithmic scales may serve to confuse rather than edify respondents, especially if the risk levels specified on the scales are inconsistent with respondents' prior beliefs.

It is somewhat puzzling that we find appropriate sensitivity of WTP to magnitude of risk reduction using dots, whereas Jones-Lee et al. (1985, 1995) found inadequate sensitivity using a similar visual aid (graph paper with 100,000 squares). The difference in results may be attributable to other differences between the studies such as the different elicitation formats (Jones-Lee et al. used payment cards and asked respondents to indicate all the payments that were acceptable, and all those that were unacceptable).

Viscusi (1985, 1989) has suggested that prior beliefs about the good may influence respondents' WTP, thereby providing an explanation for non-linearity between WTP and the reduction in mortality risk stated in the survey instrument. We find some evidence supporting this hypothesis. Perceived airbag effectiveness positively affects WTP for all visual aids. However, perceived risk and its interaction with airbag effectiveness have no consistent or significant effect.

Our results suggest that visual aids have the potential for improving the communication of small probabilities in CV studies designed to estimate WTP for reductions in mortality risks. Replication of these results in a context other than automobile safety is

needed before these conclusions can be generalized. Further, the effect of visual aids on sensitivity to magnitude of risk reduction may be quite different when probabilities span a much larger range of mortality probabilities than considered here. Further quantitative and qualitative research are needed to determine which aspects of risk-communication devices most strongly influence valuation.

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Notes

1. "Trimmed mean" estimates of WTP, £64 and £97, were obtained by omitting high outliers and likely coding errors. These WTP estimates lead to more similar estimates of VSL, £l.6 million and £1.4 million, respectively. However, median estimates of WTP for the two risk reductions are equal (£50), and yield less similar estimates of VSL, £0.7 million and £1.25 million, respectively.
2. Personal communication, John Loomis.
3. Thirty of 46 respondents offered an initial bid of $200 indicated they would be willing to purchase the airbag, and 17 of the 30 indicated they would purchase the airbag at the follow-up bid of $400.
4. The linear scale is hierarchical in that each section on the scale representing a smaller risk is proportionately smaller than the previous section.
5. Our estimate of average income is conservative as we treated income reported as "greater than or equal to $100,000" as equal to $100,000. Population means are from the 1999 Statistical Abstract of the United States.
6. In a similar study by Kidholm (1995), 945 Danes were asked to state their subjective risk of being killed in a traffic accident compared with the national average (11 in 100,000). The proportions reporting equal, lower, and higher than average risk were 54%, 38%, and 7%, respectively.
7. The estimated coefficient on "Dots" implies that WTP for the small risk reduction is 31% ($= 1 - e^{-0.374}$) smaller for the group exposed to the dots than for the reference group. The estimated coefficient on the interaction term implies that WTP for the large risk reduction is 83% ($= e^{0.606} - 1$) larger than WTP for the small risk reduction, where both WTP values are for the group exposed to the dots.

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Appendix—Visual aids

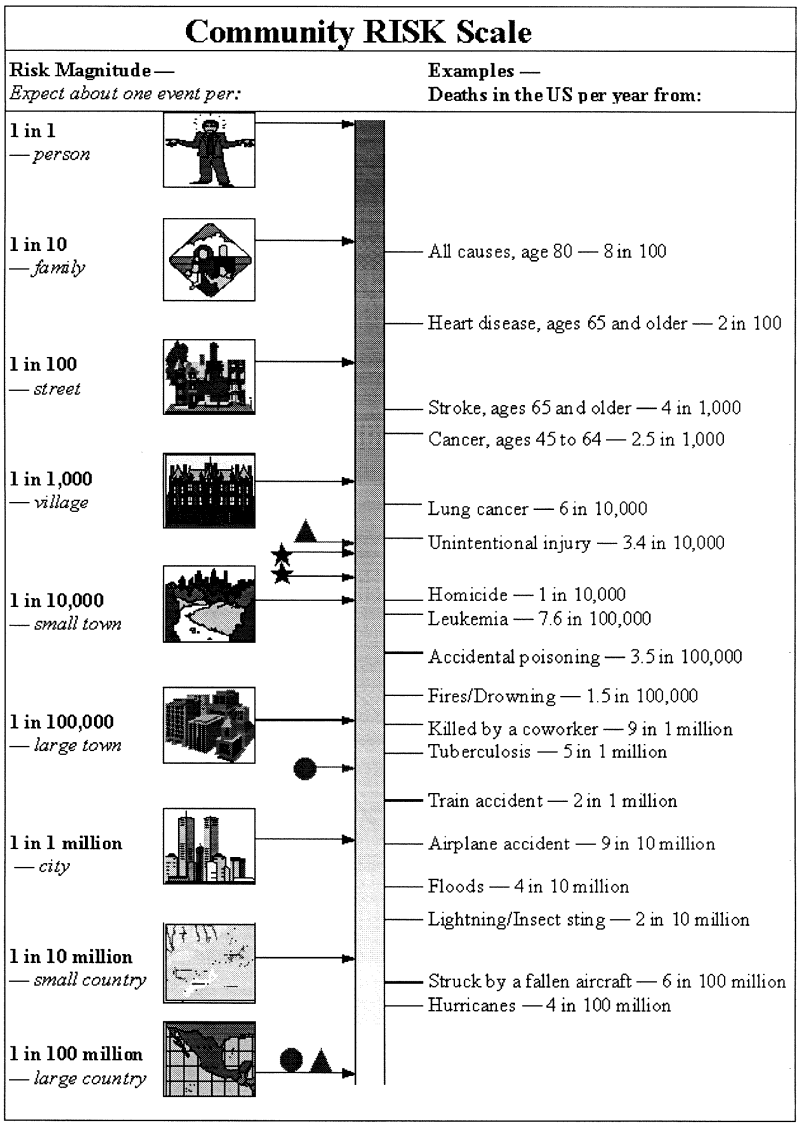

Figure 1. Logarithmic risk scale.

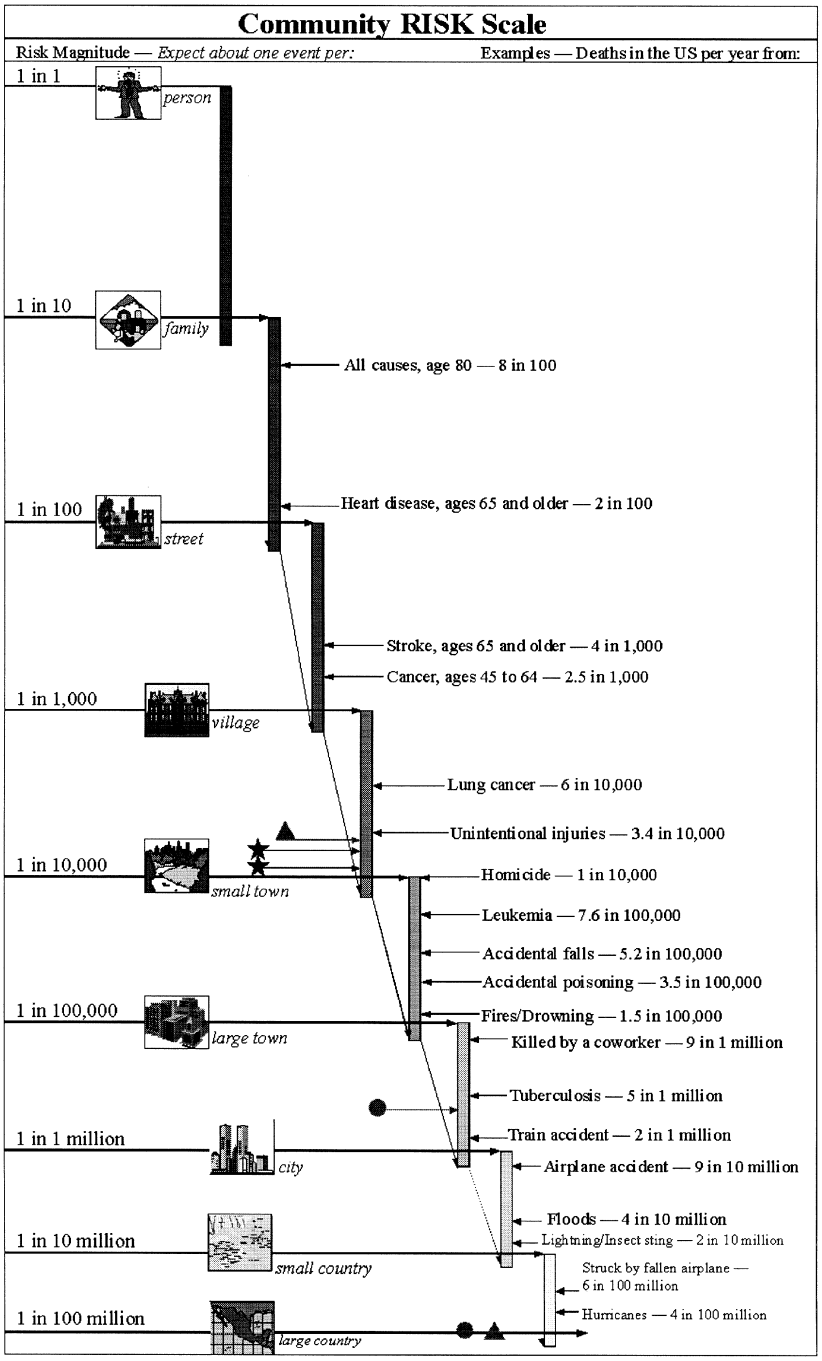

Figure 2. Linear risk scale.