ESTIMATING AN ALTRUISM ADJUSTED MEASURE OF THE VALUE OF A STATISTICAL LIFE*

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Abstract:
This paper empirically estimates an adjustment to the measure of the Value of a Statistical Life (VSL), used in benefit-cost analysis, to account for altruistic sentiments. Conventional methods for estimating a VSL have used both revealed- and stated-preference data to evaluate an individual's value of his or her *own* life. These estimates may potentially under- or overestimate the total social value of this individual to all concerned people once altruistic sentiments are included in the valuation. This paper empirically estimates Jones-Lee's (1992) VSL multiplier, which is a function of individuals' marginal rate of substitution of own wealth for others' probability of survival and marginal rate of substitution of own wealth for others' wealth. If people are more "safety-focused" altruists, then traditional benefit-cost analysis has undervalued life as a result of ignoring altruism. Conversely, if people are more "wealth-focused" altruists, then traditional benefit-cost analysis has *overvalued* life. To estimate these multipliers, I created a stated-preference survey (modeled after Krupnick et al., 2002), which was administered by Knowledge Networks to 500 survey respondents. The survey investigates altruism as a function of the other person's age and social proximity (family, friends, co-workers, acquaintances, U.S. and foreign strangers). The survey respondents demonstrate considerably more safety than wealth altruism. Consequently, the VSL altruism multiplier is substantially greater than one, suggesting we are greatly undervaluing life in federal regulatory reviews. Finally, I relate altruistic sentiments to various covariates, including distance from birth to current residence, to understand how the multiplier may change with changes to population interconnectedness and mobility.

Keywords: Benefit-cost analysis, Value of a statistical life, Altruism

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1. Introduction

1.1 Challenges in Finding the Right "Value of a Statistical Life" for use in Regulatory Policies

Numerous public policies have impacts on longevity of citizens. For example, regulations designed to reduce airborne pollutants have the potential to reduce asthma-related deaths, but may come at the cost of businesses having to expend resources to retrofit factories to reduce emissions. A decision to raise highway speeds may be valued by travelers who can lower their travel times, but come at the cost of increased deaths caused by traffic accidents at high speeds. In regulatory analyses of these policies, benefit-cost analysts are asked to estimate whether the benefits of these policies outweigh their costs.[1] Understanding how to value a life saved (or more accurately extended) is critical for the efficacy of these benefit-cost analyses.

The federal government has a large stake in having an accurate measure for what is known as the "Value of a Statistical Life" (VSL).[2] Executive Order 12866 requires numerous regulatory policies to be evaluated each year by the White House's Office of Information and Regulatory Affairs. Yet, there is wide variation across agencies in the VSL that is used. For example, Applebaum (2011) reports that $9.1 million and around $6 million were used as VSLs, respectively, by the Environmental Protection Agency and the Transportation Department in 2011. These variations can have large consequences in

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[1] Most benefit-cost analyses are justified by the Kaldor-Hicks Criterion, which asks whether the winners of a given policy could compensate the losers such that no one is worse off when a policy is adopted (Kaldor (1939), Hicks (1939)).

[2] The term "Value of a Statistical Life" (VSL) is used in the literature, but is somewhat inelegant and misleading. The word "Statistical" is used because the identity of those whose lives are saved or lost as a result of the policy are unknown in prospective and some retrospective benefit-cost analyses. Rather, what is known is that the policy raises or lowers each citizen's probability of death by some fractional amount. We can value each citizen's change in the probability of death (i.e., the cash amount the individual would be willing to pay (accept) in exchange for a lower (higher) chance of death). Then, summing the change in the probability of death across citizens until we arrive at one life saved (lost) by the policy and simultaneously adding up the valuations gives us the value of one "statistical life." Cameron (2010) critiques the term VSL and argues that it gives a misleading impression to the public and to policymakers. She proposes the use of "Willingness-to-Swap for a Microrisk Reduction" as a more accurate term. This phrase has the advantage of illustrating that what we are really considering is whether the public is willing to swap something (e.g., travel time) for the additional small risk of death. Although I agree with Cameron's critique, her term is not yet standard (and is itself cumbersome), so I am using the term "VSL" in this paper.

determining whether a regulation passes the benefit-cost test, and thus affects what public policies are adopted or rejected.

Most studies that attempt to value life use market transactions which reveal the amount of money a person needs to be paid to accept some small amount of risk of death or the person's willingness to pay to reduce their risk of death. Often these studies are based on revealed preferences via market transactions. For example, wage differentials that must be paid to workers in risky jobs, or expenditures made by individuals on safety equipment (e.g., car air bags) that may preserve/extend their lives. Mrozek and Taylor (2002) report valuations of life estimates coming from wage studies using "best practices" ranging from $1.5 to $2.5 million (in 1998 dollars), while Viscusi and Aldy (2003) report a median value of $7 million (in 2000 dollars) in the studies they summarize. Alternatively, contingent valuation studies ask survey respondents how much money they would need to be paid to accept death or an increase in the probability of death. Krupnick (2007) reports valuations of life from contingent valuation studies ranging from $210,000 to $6,290,000.

Recently, scholars have tried to determine whether the VSL rises or falls as a person ages. Part of this effort has been to estimate the appropriate VSL for children using parents' revealed preferences. For example, Jenkins, Owens, and Wiggins (2001) use expenditures on bicycle helmets and find that adults place more value on their own lives than on their children's lives. Likewise, Carlin and Sandy (1991) use expenditures on car seats and find valuations of child lives that are less than typical valuations of adult lives. From a review of several studies, Aldy and Viscusi (2007) conclude that the value of life is lower for children and older-aged people, and is highest for middle-aged people. Yet, in another review article, Blomquist (2004, p. 89) notes that "some evidence suggests that values for children and seniors are not less than middle-aged adults." In evaluating expenditures on safety equipment in cars as a function of family composition and ages, Kim (2004) finds more expenditure on children than adults, and declining spending as an individual ages. Using contingent valuation/stated preference surveys, both Liu and colleagues (Liu, Hammitt, Wang, & Liu, 2000) and Dickie and Messman (2004) find that parents are willing to pay twice as much to prevent the death and illness of their children as they are willing to pay to prevent their own death and illness. Thus, the existing literature has reached contradictory findings.

Given the uncertainty in the literature about the relationship between age and the value of life (and the ethical issues involved), it is unsurprising that the U.S. Office of Management and Budget has recommended against adjustment for the age of beneficiaries/victims in agencies benefit-cost analyses

(Graham 2003). A recent panel convened by the Environmental Protection Agency (Cropper et al., 2007) concluded:

> "Although the literature on the relationship between age and the VSL [Value of a Statistical Life] is growing, the Committee does not believe that it is sufficiently robust to allow the Agency to use a VSL that varies with age. The Committee also believes that the use of a constant Value of a Statistical Life Year (VSLY), which assumes that the VSL is strictly proportional to remaining life expectancy, is unwarranted. If there is insufficient information to indicate that the VSL declines with age, there is not sufficient information to indicate that the VSL is strictly proportional to remaining life expectancy" (p. ii).

The National Academy of Sciences (2008) reviewed the evidence on the relationship between age and value of life. They conclude that there is insufficient evidence on the relationship between the value of life and age:

> "…if we know from the cause of death associated with ozone exposure that the mortality risk is primarily for respiratory causes of death, we know that the age distribution of the at-risk population is skewed more toward the elderly, especially those experiencing cardiopulmonary compromise, than is total mortality in the general population. Thus, the [willingness to pay] estimates should be relevant for a population with a higher average age. The currently available information lacks that level of detail" (p. 170).

1.2 The Role of Altruism in the VSL

Even if we get the age adjustments right for the valuation of a person's life to themselves, we have the challenge that these valuations may not completely capture the full value of life to all affected parties. If the individual making a market transaction (e.g., a worker taking on a risky job) doesn't consider the "the pain and suffering of friends and relatives some of whom may be economically dependent" on the person deciding the market transaction, then standard benefit-cost analysis will undervalue the person's life (Gramlich, 1990, p. 68).

Valuation of other's lives outside of the family has been notably absent in most of the prior literature. Birchenall and Soares (2009) argue that incorporating altruism (i.e., the value placed on other's lives) into a cost-benefit analysis leads to a doubling in "the estimated welfare gain of a young adult from [recent] reductions in mortality" in the U.S.

However, work by Bergstrom (1982) suggest that there may need to be no adjustment to account for altruism if that altruism is "pure" in the sense that individuals care about the utility of others rather than primarily care about others' probability of survival. The intuition for this result is as follows: if person A cares about person B's probability of survival and wealth (net of taxation) in the same proportion as person B cares about his own wealth and own probability of survival, then person A would not be willing to pay more (via a tax levied on person B) for a public safety program than person B is willing to tax himself.

Jones-Lee (1992) extends Bergstrom (1982) and derives the following formula (assuming altruism exists solely within families); the value of life that should be used in benefit-cost analysis is equal to the population mean of:

$$(1) \qquad m_{ii}\left[\frac{1+(x_k-1)\frac{m_{ki}}{m_{ii}}}{1+(x_k-1)n_k}\right]$$

where m_{ii} = marginal rate of substitution of own wealth for own probability of survival, m_{ki} = marginal rate of substitution of own wealth for family members' probability of survival, n_k = marginal rate of substitution of own wealth for family members' wealth, and x_k = number of family members. Note that if people are pure altruists (i.e., $m_{ki}/m_{ii} = n_k$) then the above expression reduces down to m_{ii}, which is the value used in traditional benefit-costs analysis (if assuming a constant value of own life across the population: $m_{ii} = m_{jj} = m$), and this result reproduces the Bergstrom (1982) result. If people are more "safety-focused" altruists (i.e., $m_{ki}/m_{ii} > n_k$), then the value in brackets is greater than one, implying that traditional benefit-cost analysis has undervalued life as a result of ignoring altruism. Finally, if people are more "wealth-focused" altruists (i.e., $m_{ki}/m_{ii} < n_k$), then the value in brackets is less than one, implying that traditional benefit-cost analysis has *overvalued* life. Jones-Lee notes that there is no existing data on the joint distribution of m_{ki}/m_{ii} and n_k.

The objective of this paper is to provide the first empirical estimate of the Jones-Lee Multiplier (i.e., the term in brackets in Equation 1) and to assess whether this multiplier is greater or less than one. However, I additionally move past Jones-Lee's theoretical contribution by relaxing his assumption that altruistic sentiments only occur within families and relaxing the assumption that the public project has uniform effects on the population's safety. As shown in mathematical Appendix A, using the more general assumption that individual *i* can have safety and wealth altruism for any other individual *j*, I show that the value of life that should be used in benefit-cost analysis is equal to the following[3]:

[3] Derivation of this multiplier requires the assumption of a constant value of own life across the population (i.e., $m_{ii} = m_{jj}$). I do not necessarily believe that this assumption is warranted, but it needs to be used as the starting point for this analysis given the current literature's lack of consensus on whether there exists heterogeneity in m_{ii}. Given that I find evidence to suggest that the multiplier

$$(2) \qquad m_{ii}\left[\left(N'^{-1} \times W\right) \times (M \times D)\right]$$

where N reflects wealth altruism as an n×n matrix of n_{ji} / n_{ii} (i.e., $\frac{\partial \mathrm{w_j}}{\partial \mathrm{w_i}}$ or the marginal willingness of person i to forgo own wealth for a gain in person j's wealth); W is a n×1 matrix of ones; M reflects safety altruism as an n×n matrix of m_{ji} / m_{ii} (i.e., $\frac{\partial \pi_j}{\partial w_i} / \frac{\partial \pi_i}{\partial w_i} = \frac{\partial \pi_j}{\partial \pi_i}$, or the marginal willingness of person i to forgo own probability of survival for a gain in person j's probability of survival); and D is an n×1 matrix reflecting the effect of the public project on each individual's probability of survival (i.e., $\frac{\partial \pi_i}{\partial s}$). Policies that mostly affect older or younger individuals (e.g., investments in cancer research or requirements for bicycle helmets) will have different altruism multipliers if the relative balance between safety and wealth altruism varies by the age of the people under consideration. That is, if citizens are more safety altruistic towards children and more wealth altruistic towards the elderly (or vice-versa), then policies that affect children's safety would have a bigger (smaller) multiplier that policies that effect the elderly.

I have two secondary objectives. First, I seek to understand how social proximity and age of the other person affect altruistic sentiments. I produce estimates of wealth and safety altruism for others in ten age groups (0-4, 5-9, …,70-79, 80+) and seven social proximity groups (immediate and extended family, close friends, co-workers, acquaintances, U.S. strangers, and foreign strangers). Second, I seek to understand how population mobility affects altruistic sentiments and thus to estimate how the Jones-Lee Multiplier may change with a more or less mobile population and a more or less tightly connected population.[4]

2. Methods

2.1 Survey Design to Match Theoretical Constructs With Empirical Estimates

There are strong empirical challenges in estimating the elements needed to compute the Jones-Lee Multiplier. This multiplier (when expanded to allow for altruism outside the family) consists of the joint distribution of safety altruism, wealth altruism, and the effect of the policy on the likelihood of an individual dying. This joint distribution depends on the number and type of social relations an individual has, and the tightness of social networks (i.e., degrees of separation between individuals).

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appears to be substantially greater than one, there is good reason to produce future research that would relax this assumption.

[4] American migration reached a record low in 2011 (Rampell, 2011). Yet, growth in telecommunications and the rise of Facebook and other social media yield increases an individuals' interconnectedness (Backstrom, 2011; Ugander et al., 2011; Backstrom et al., 2011).

Safety altruism $\left(\frac{m_{ji}}{m_{ii}} = \frac{\partial \pi_j}{\partial \pi_i}\right)$ is the most difficult term to estimate since there are not real-world contexts where the typical person is "revealed" to show his/her valuation of own safety relative to another's safety (i.e., the marginal willingness of person *i* to exchange a slight increase in the probability of his or her own death for a slight decrease in the probability of person *j*'s death). As such, it is necessary to use survey-based stated preferences to estimate safety altruism.

Wealth altruism $\left(\frac{n_{ji}}{n_{ii}} = \frac{\partial w_j}{\partial w_i}\right)$ does have real-world behavior (e.g., charitable donations) and experiments (e.g., "dictator games") from which to estimate this wealth altruism.[5] Yet for the purposes of estimating the multiplier, I will again use stated preferences. I have constructed a survey to elicit estimates of safety and wealth altruism with questions that are structured in a parallel fashion such that if the results yield biased estimates of altruism, it is hoped that the biases are of comparable magnitudes such that they cancel out. For example, returning to Equation 2, if the estimates for $\frac{m_{ji}}{m_{ii}}$ and $\frac{n_{ji}}{n_{ii}}$ are biased upwards (or downwards) by the same percentage amount, these biases will cancel.

Appendix B provides the full survey. The graphics used in these survey questions as well as some of the preliminary questions designed to explain probability and test understanding were designed to mimic the contingent valuation work in Krupnick et al. (2002).[6] The key questions revolve around a hypothetical scenario comparable to a dictator game. In the first set of questions, which measure safety altruism, the respondent is told that a company is prepared to distribute 10 medical products or safety inventions, where each product/invention will lower the recipient's chance of death during the next ten years by one chance in 1,000. The respondent is told that the company has asked the respondent to allocate the 10 medical products and safety inventions between himself/herself and one other person, with the age and social relation of the other person given in the question. The respondent is provided 10 variants of this question, each of which varies the age and social relation of the other person.

A parallel scenario is presented to measure wealth altruism: the respondent is told that the company is prepared to distribute 10 scratch-off tickets, where each ticket has one chance in 1,000 of

[5] In dictator games, one study participant (the "dictator") is given the opportunity to divide a fixed amount of money between themselves and another study participant. In a meta study summarizing the results of 131 papers containing a total of 616 different treatments, Engel (2011) finds that the dictators on average gave away 28% of the money to the other participant. As shown below, this average amount of revealed preference wealth altruism corresponds quite closely to the stated preference results in my survey (which had a global raw mean of 0.277).

[6] The survey also includes the Krupnick et al. (2002) contingent valuation questions to assess the respondent's valuations of themselves (i.e., m_{ii}) so that this valuation can be compared to estimates in the existing literature. These questions will be analyzed in subsequent research.

winning $25,000 from the company. The respondent is again asked to allocate the 10 tickets between himself/herself and one other person, with the age and social relation of the other person given in the question. Again, 10 variants of this question are asked.

Knowledge Networks (KN) fielded the survey to 528 members of their KnowledgePanel®, which is an online panel based on a representative sample of the full U.S. population.[7] I dropped from the analysis 32 respondents who answered fewer than 10 of the 20 questions measuring wealth and safety altruism, leaving an analysis sample with 496 respondents. KN provided survey weights to make the sample of 496 respondents representative of the full U.S. population and these weights are used to produce descriptive statistics and in regression analysis. The survey took 23 minutes to complete for the median respondent.

To evaluate what factors are associated with altruistic sentiments, I regress the amount that the respondent allocates to the other person on indicators for the social relation between the respondent and the other person; indicators for the age group of the other person; the respondent's sex, age, and age-squared; indicator variables for distance from birth state[8]; and three survey framing factors (indicators for whether safety altruism questions were asked first, whether the respondent was placed on the left or right of the screen, and the interaction of these framing indicators). To investigate whether framing influenced responses, half of the survey respondents were asked the set of 10 wealth altruism questions before the set of 10 safety altruism questions. Additionally, whether the "other person" was shown on the left or right of the screen was randomized.[9] There are 70 possible combinations of age and social relation of the other person[10], and each survey respondent is asked about only 10 of these combinations in each set of wealth and safety altruism questions, and the set of questions each respondent answered

[7] http://www.knowledgenetworks.com/knpanel/index.html. The survey was pre-tested by 36 of KN's respondents. There were no substantial challenges found in the pre-test, and no changes were made to the survey.

[8] The base case is a respondent who resides in their birth state. The indicators included: whether the respondent was born outside the U.S. or in a state whose population-weighted centroid is less than 500, 501 to 1,000, or greater than 1,000 miles from the population-weighted centroid of the respondent's state of residence. State population centroids are taken from the 2010 U.S. Census.

[9] See pp. 32 of Appendix B. For half of the sample, the "You" column was set to the left of the "Other person" column, and for the remainder of the sample, the "You" column was on the right.

[10] Ten age groups (0-4, 5-9, 10-17, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80+) and seven social proximity groups (immediate and extended family, close friends, co-workers, acquaintances, U.S. strangers, and foreign strangers).

varied across the sample.[11] Since each respondent contributes 10 observations to each regression, I compute robust standard errors clustered by respondent.

2.2 Construction of the Matrices: Establishing Social Relations Between Persons i and j

To estimate the multiplier shown in Equation 2, it is necessary to establish the size of the *M* and *N* matrices, and the values to be placed in these matrices. If we were to incorporate valuations of any person in the world, then the size of these matrices would be based on the world's population (i.e., 7+ billion × 7+ billion). Obviously it would be impossible to establish such a matrix. Thus, I take a more feasible approach by initially setting the size of the matrix to 625×625 (which reflects the 496 respondents plus their 129 simulated minor children[12]). I then show how the multiplier evolves as this population size is doubled (to 1,250×1,250) and tripled (to 1,875×1,875). Note that as the population size is increased, (given a fixed number of family members, friends, co-workers, and acquaintances) the share of the matrix that is comprised of strangers grows.

Starting with the 625×625 matrix, I define all relationships between person *i* and person *j* in a manner that tries to mimic the survey respondent's stated number and ages of family members, friends, co-workers, and acquaintances. Details of how these relationships are defined are included in Appendix C. In brief, I begin by finding the "best" spouse for each respondent who reports that they are married. The best spouse will be the one with the smallest deviation of respondent *i*'s age group, from the age of respondent *j*'s spouse (and vice-versa), and the best compatibility in terms of relationships that should be symmetric (such as age and number of children). Then, I assign children (minors and non-minors) to married and single parents, and establish the resulting sibling relationships. Once all parent-child-sibling relationships are established, I then establish all of the resulting extended family relationships (e.g., aunts, uncles, and cousins). Next, I establish close friend relationships so as to match each respondent's number and ages of close friends. I repeat this process to establish co-workers and then acquaintances. The remaining non-established relationships are set to be strangers.

[11] Survey respondents are only asked about relationships that the respondent actually has. Thus, for example the respondent is only given a question about safety altruism towards an immediate family member age 10-17 if the respondent reported having such a relationship in earlier questions. As another example, no one was asked wealth and safety altruism questions about co-workers who are under the age of 10, as none of the survey respondents reported such relationships.

[12] The survey respondents reported having a total number of 258 children age 0-17. I divide this number by 2, on the assumption that most minor children have two living parents. In reality, I am slightly under-estimating the share of minors in the population.

To establish close friend, co-worker, and acquaintance relationships, I take two polar extreme positions. In my “base” case, I use the “loosest” possible approach, which randomly selects an *i* and a *j*, and establishes the relationship between the two if *i* and *j* do not have an already established relationship, and *i* and *j* are each seeking a relation with a person of the other’s type. For example, if individual *i* is 25 years old and reports having a close friend age 30-39, and individual *j* is 34 years old and reports having a close friend age 20-29, and *i* and *j* have not as yet been assigned a relationship, then they will be established as being close friends. This “loose” approach (which randomly selects *i* and *j* to identify possible relationships) yields a society that has the fewest possible degrees of separation between pairs of individuals. As an alternative to this base method, I use the “tightest” possible approach, which seeks out persons *i* and *j* that are closest to the diagonal of the matrix. This tight approach yields a matrix that has the most degrees of separation between pairs of individuals.

These two extreme approaches are illustrated in Table 1 and Figures 1 and 2 using hypothetical data for six individuals (Su, Gary, Stu, Mary, Bill, and Jen). Table 1 gives the number of friends of each respondent and their valuation of the other person relative to their valuation of themselves. For example, Su reports being in a family with only one person (herself) and has 3 friends and 5 acquaintances.

[Insert Table 1]

In Figures 1 and 2, I show an 18×18 community whose members have the family, friends, and acquaintance relationships defined by six survey respondents, each hypothetical respondent entered three times as if they represent three distinct persons. Figure 1 shows the “tight” approach to allocating relationships. First, I start by defining families (shown in yellow). Su (as well as Su2 and Su3) is in a family by herself. Gary and Stu are placed in a family as they each report being in a family with two members (this is a simplified version of the approach I actually take, which matches family members on a longer list of attributes). Mary, Bill, and Jen are placed in a family as they each report being in a family with three members. Next, I establish friends (shown in green). The “tight” approach selects Su’s friends as those that are geographically closest to Su and have available friendships (i.e., Gary, Mary, and Bill). Stu is skipped as Stu reports having no friends, thus he cannot be Su’s friend. Since Gary has 2 friends, he is allocated one more friend, Mary, who is the geographically closest possible friend to Gary. And so on. After friendships have been established, acquaintance relationships are defined (shown in blue) using the same procedure. Finally, the remaining relationships are strangers (shown in red). This “tight” approach yields “communities” that have little connection to one another.

For example, Su, Gary, and Stu in the upper-left have no non-stranger relationships to Stu3, Su3, and Bill3 in the bottom-right.[13]

[Insert Figure 1]

In contrast, the "loose" approach shown in Figure 2 presents a very different set of relationships. Family relationships are established as before. However, the cells for friend and possible acquaintance relationships are selected randomly. As a consequence, there are strong ties across the matrix and less isolated communities. By using these two extreme assumptions, I hope to show how denser networks affect the size of the VSL multiplier, and thus to understand how increasing connectedness provided by telecommunications (but decreasing connectedness due to reductions in physical mobility) may affect the VSL.

[Insert Figure 2]

Since the matrix of relationships includes a random component, I create 25 versions of each matrix, compute the VSL multiplier for each matrix, and report the median VSL multiplier from these 25 estimates.

2.3 Construction of the Matrices: Filling in Person i's Altruistic Sentiments Regarding Person j

After establishing all of the relationships in the matrices, the next task is to add valuations to the matrices. I begin by estimating the safety valuation of person *i* towards person *j* (i.e., the amount out of 10 medical devices / safety inventions that person *i* is predicted to allocate to person *j*) using the results of the regression discussed above in Section 2.1 as follows:

$$(3)\ \widehat{valuation}_{ij} = \hat{\alpha} + R_{ij}{}'\hat{\beta}_R + A_j'\hat{\beta}_A + 0.5\hat{\beta}_{Female} + Age_i\hat{\beta}_{Age} + {Age_i}^2\hat{\beta}_{Age^2} + 0.5\hat{\beta}_{SafetyAskedFirst} + 0.5\hat{\beta}_{OtherPersonOnLeft} + 0.25\hat{\beta}_{Interaction}$$

R_{ij} is a vector of indicators reflecting the assigned relationship between *i* and *j*, A_j is a vector of indicators for person *j*'s age group. The valuation varies based on the respondent's age (so as to

[13] Note further that as shown in the last two columns in Figure 1, this approach may not leave all relationships defined. For example, Mary3 has four friends (as shown in Table 1) but is only assigned one bilateral friendship. The problem is that there are no other persons who are not Mary3's family members who have not exhausted their number of friendships by the time I get to defining Mary3's friends. As a result, it is not possible to give bilateral friendships that perfectly match each respondent's reported number of friends. In the actual program, before I would move past a particular relationship type (e.g., from close friend to co-worker) I fill in missing relationships in a unilateral way. For example, I would assign Mary3 as having person *j* as Mary3's friend if (a) person *j* is closest to the diagonal and (b) person *j* has some friends (even though person *j*'s friends have already been established). Condition (b) says that such a bilateral relation between person Mary3 and person *j could* exist. I do not assign Mary3 to be person *j*'s friend, which leaves some relationships as unilateral.

preserve a real world age distribution and connection of the real world age distribution with relationship types), but otherwise assigns values to the respondent (female=0.5, framing issues set at their mean values, and assumes that the individual resides in their state of birth). To explore how a more mobile population is likely to affect the VSL multiplier, I add $\hat{\beta}_{Residence\_1000+\_Miles\_From\_Birth\_State}$ to the valuation estimate in Equation 3. For reasons discussed below, for all minor children, I restrict the value of $\widehat{valuation}_{ij}$ to not exceed the valuations of adults for that age-relationship type of the other person. Finally, if $\widehat{valuation}_{ij}$is greater that 10 (less than 0), I reset $\widehat{valuation}_{ij}$ to 10 (0).

Next, for each entry placed in the *M* matrix, which reflect safety altruism and are equal to $\frac{\partial \pi_j}{\partial \pi_i}$, I convert the safety altruism valuations given by Equation 3 into their implied marginal valuations. To do so, the value placed in the *M* matrix is equal $\widehat{valuation}_{ij}$ / (1-$\widehat{valuation}_{ij}$).[14] Thus, for example, if individual *j* is predicted to allocate 2 medical/safety devices to the other person and 8 to himself, then $\frac{\partial \pi_j}{\partial \pi_i}$ is estimated as 2/8 = 0.25. To see that this makes sense, note that if the respondent had a substantially different implicit value of $\frac{\partial \pi_j}{\partial \pi_i}$, they would have cause to seek a different allocation of the medical/safety devices that more closely traded off their risk of death for the other person's risk of death. The same process is repeated using the wealth altruism survey responses and estimated coefficients to create the elements in the *N* matrix.

To compute a standard error on the median VSL multiplier, I use a bootstrapping approach describes as follows. First, I add a random error distributed Normal(0, ${\sigma_{\widehat{valuation}_{ij}}}^2$) to the valuation in Equation (3), where ${\sigma_{\widehat{valuation}_{ij}}}^2$ is the estimated error variance in the prediction of $valuation_{ij}$. I then compute the VSL multiplier for the matrix. I then repeat this process for each of the 25 matrices and find the median VSL multiplier from these 25 matrices. I store this median VSL multiplier and then repeat this process 50 times, which produces 50 median VSL multipliers. I compute the standard deviation of these 50 median VSL multipliers which yields the estimate of the standard error on the median VSL multiplier.

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[14] However, if $\widehat{valuation}_{ij}$ is equal to 10 (i.e., the individual is estimated to allocate 0 medical/safety devices to self and 10 to the other person), then the value placed in the *M* matrix is set at 25. The reason that this cap is placed is that the survey construction with discrete choices of 0 to 10 does not effectively allow us to probe the difference between very high and infinite altruism. The value of 25 was derived by fitting 7th and 8th order polynomials to extend the following conversions: 10→0, 9→0.111, 8→0.25, 7→0.429, 6→0.667, 5→1, 4→1.5, 3→2.33, 2→4, 1→9, 0→unknown, which respectively produced predicted values of 24.3 and 26.4 for the unknown value

2.3 Simulations

My "base" case has the following assumptions: (1) close friends, co-workers, and acquaintances are assigned using the "loose" approach, (2) all persons live in their state of birth, (3) valuations of strangers are based on respondents' valuations of U.S. strangers, and (4) the population has 625 members. I vary the base assumptions in the following ways: (1) assigning close friends, co-workers, and acquaintances using the "tight" approach; (2) assuming all persons live 1,000+ miles from the state of their birth; (3) using valuations of strangers that are based on respondents' valuations of foreign strangers; and (4) raising the population to 1,250 and 1,850 members.

For each of these permutations, I make various assumptions about how the public policy affects survival probabilities by age groups. First, I assume that each person receives an equal-sized increase in his/her survival probability and the public policy saves one life in expectation (e.g., that each element of the D matrix equals 1/625 given a population of 625). Then, I assume that the public policy only affects the survival probability of those in one particular age group (e.g., only affecting those age 0-4) and that each member of this age group has their probability of survival raised by $1/K$, where K is the number of members of that age group. With these simulations, I will show the extent of the change in the multiplier under various conditions.

3. Results

3.1 Descriptive Statistics and Factors Predicting Altruistic Sentiments

Of the 496 sample participants, 256 were male and the average age was 48.4 (range = 18-87). The average respondent reported 7.2 close friends (s.d.=11.1, max = 100), 10.7 co-workers (s.d.=53.8, max = 1.000), and 61.8 acquaintances (s.d. = 122.1, max = 1,300).

Figure 3 shows the raw, unadjusted mean values given for the set of safety-altruism questions.[15] For most age-relationship combinations, the respondents reported being willing to split the medical devices / safety inventions roughly equally between themselves and the other person, with most mean values in the range of 3.5 to 6 given to the other person (with a global, raw mean of 4.34). Not surprisingly, respondents generally had the highest level of safety altruism with respect to immediate family members and the least with respect to foreign strangers. Wealth altruism generally falls with

[15] I exclude from this figure the means that are computed based on less than 10 responses for a particular age/relationship type. For example, I do not show the mean responses for the two individuals who reported who having a close-friend age 0-4 and who were asked about their preferences for allocation of medical/safety devices regarding this relationship.

respect to the age of the other person. Figure 4 shows the same computations for the set of wealth-altruism questions. The mean values lie mostly in the range of 2 to 4 scratch-off tickets given to the other person (with a global, raw mean of 2.77). From these figures, we can graphically see that multiplier is likely to be greater than one since respondents are generally indicating more of a preference for safety altruism than wealth altruism.

[Insert Figures 3 & 4]

Table 2 shows the results of regressions predicting the respondent's level of altruism as a function of the age-relationship of the other person and characteristics of the respondent. Respondents gave less to all relationship types relative to immediate family members, and these differences were statistically significant with the exception of close friends. Safety altruism was highest for those age 0-4 and 60-69, and significantly lower for age 18-29 and 80 and older. Wealth altruism was highest for those age 10-29 and 60-69 and lowest for those age 0-4, yet the coefficients on age of the other person is not jointly significant.

[Insert Table 2]

Gender was a non-factor in altruistic sentiments. There was a strong relationship between respondent age and safety altruism, but little age effect on wealth altruism. These patterns are shown in Figure 5, where safety altruism declines rapidly with age, is lowest at age 59, and then rises rapidly with age, whereas wealth altruism barely changes with age of respondent. Given this strong relationship between age of the respondent and safety altruism, which would yield *very* high safety altruism for minors if the pattern was extrapolated, to be conservative, I restrict minors levels of altruism to not exceed adults maximum and minimum levels of altruism for each age-relationship type of the other person.

[Insert Figure 5]

Returning to Table 2, I find that both safety and wealth altruism is highest for those who reside in their birth state, and these differences are significant for wealth altruism for those who reside 500-999 and 1,000+ miles away from their birth state, yet the four coefficients are not jointly significant in either regression. Finally, I find that framing affected responses for safety altruism (where the three coefficients are jointly significant) but did not significantly affect wealth altruism. Both wealth and safety altruism were higher if safety altruism questions were asked first, and this framing effect is greater if the other person was graphically shown on the left of the screen and the respondent on the right (such that, reading from left to right, the respondent would cross over the other person before answering how much they gave to themselves), although none of the framing effect coefficients are individually significant.

3.2 Estimates of the VSL Multiplier Under Various Scenarios

Before presenting the estimates of the VSL multiplier (i.e., $\left[\left(N'^{-1} \times W\right) \times (M \times D)\right]$ from Equation 2), I take a simpler approach. First I compute the means of all of the elements in the *M* and *N* matrices.[16] These means reflect the average amount of safety and wealth altruism in the simulated population. Then I take compute the ratio of these two means. To yield a standard error on the ratio of the means, I repeat this process 50 times with error added to the prediction of safety and wealth altruism elements in the *M* and *N* matrices, compute the means, the ratio of the means, and finally the standard deviation across these 50 ratios. The ratios and standard errors of the ratios are shown in Table 3.

[Insert Table 3]

Column 1 contains the base specification. As shown in Panel A, I find that if the public policy has a uniform effect on public safety, then the ratio of the average element in the *M* matrix to the average element in the *N* matrix is 2.2 and, given a standard error of 0.2, this ratio is significantly higher than one. These results suggest that on average person's marginal willingness to increase their chance of death for a reduction in another's chance of death is ***more than double*** the average person's marginal willingness to reduce their wealth for an increase in another's wealth. As a result, we should expect that the VSL multiplier should be roughly equal to 2 or somewhat above. The subsequent rows of Panel A of Table 2 show that this ratio remains substantially above 1 regardless of what age group is affected by the public policy, and is highest for policies that affect the safety of those age 0-4 and 5-9, for which the ratios average 3.0 and 2.6 respectively. Columns 2-4 reveal very little variation in the ratio of the mean valuations based on the tightness of social networks, the mobility of the population, or whether the valuations of strangers are assumed to based on foreigners or domestic strangers. (Results for Columns 5 and 6 will be available in the next iteration of this paper).

Since the ratio of safety altruism to wealth altruism is projected to widen as one estimates these valuations for younger and younger persons (as shown in Figure 5), it is more conservative to not include estimated valuations by minors. Thus, in Panel B of Table 3, I repeat these estimates restricted to only adults. The estimated ratios are somewhat smaller than those shown in Panel A, but still are

[16] These computations are performed on just the first of the 25 matrices of relationships that are discussed in Section 2.2 as they vary little across these matrices.

mostly around 2. <u>These results suggest that consideration of altruistic sentiments should yield a doubling of the VSL used in benefit-cost analyses.</u>

Table 4 contains the direct estimates of the VSL multiplier $\left[\left({N'}^{-1} \times W\right) \times (M \times D)\right]$. These results should be taken with *substantial caution* as the estimated multipliers are very unstable depending on the nature of the estimated relationships between persons. Column 1 contains the base specification. I find that if the public policy has a uniform effect on public safety, then the median VSL multiplier is 7.3 and this estimate is significantly higher than one. However, the estimated VSL multipliers *varied widely* across the 25 matrices of relationships. The five most central values among the 25 estimates ranged from 3.7 to 9.3, the nine most central values ranged from 1.1 to 13.0, and 6 of the estimates were negative! Negative values would imply that altruistic sentiments, nonsensically, would lead the public to want to pay for some person's death. Obtaining a negative multiplier is possible even with a small population, each of whom gives positive value to each other. For example, the following matrices $\left(N = \begin{bmatrix} 1 & 0.1 \\ 3 & 1 \end{bmatrix}, M = \begin{bmatrix} 1 & 0.5 \\ 0.5 & 1 \end{bmatrix}, D = \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix}\right)$ reflect a two-person world, where each person holds positive regard for the other, and which nonetheless yields a negative VSL multiplier (-1.2). Such a strange result should give us some hesitation in attempting to directly estimate the VSL multiplier.

[Insert Table 4]

Despite some nonsensical estimates, there are some general patterns worthy of note in Table 4. First note that all of the estimates are greater than one (ranging from 1.1 to 10.9) and most are greater than 2. By yielding point estimates that are generally the same or larger than those shown in Table 3, these results would seem to suggest that the nature of the relationships in a society is unlikely to overturn the result found by the simple computation of the ratio of mean safety altruism to mean wealth altruism. That is, there is little in Table 4 that leads me to not believe that the "true" multiplier is not around 2, as suggested by the results of Table 3. Yet, aside from the base specification, where the results are quite high and range from 6.0 to 10.9, most of the estimates of the VSL multiplier are not significantly greater than one due to the high variance across matrices in the estimates.[17]

(Results for Columns 5 and 6 will be available in the next iteration of this paper).

[17] At the time of this writing, results were not complete for the standard errors on the fourth column. What is shown in the fourth column is the standard deviation of the estimated median VSL multiplier using the first 8 of 50 loops through the program.

4. Conclusion

In this paper, I show that the presence and *nature* of altruistic sentiments yields a *social* Value of a Statistical Life that is substantially and significantly higher that what is used in currently federal policy, which ignores altruistic sentiments and bases VSLs on individuals' valuations of themselves. This result occurs because people report caring more for the safety of others than the wealth of others (and consequently would be more willing to tax others to pay for public projects that raises public safety than these others would be willing to tax themselves). Further, I find that the social VSL including altruistic sentiments is highest for policies that affect the safety of young children (ages 0-4 and 5-9) for whom safety altruism is around 3 times higher than wealth altruism (suggesting that the VSL for children should be nearly tripled).

These results should, of course, be taken with a grain of salt as they are based on stated preferences for giving, and these may be substantially greater than true, unobserved altruistic preferences. However, given the size of the estimated VSL multiplier, these results should cause public officials to question their methods and academic researchers to seek additional methods to estimate this multiplier. Estimating this multiplier is challenging as there are few contexts in which the public is able to reveal their preferences and show their willingness to trade off their own probability of death for another's probability of death. Yet, even if the stated preferences in this research yield biased estimates of the unobserved altruistic preferences that would be revealed in real-world behavior (if such contexts existed), these results may still be valid as they reveal the public's altruistic aspirations. There is a reasonable argument that the VSL that should be used in regulatory analysis should be based on such aspirations as they correspond to the public's desired valuations.

It should be noted that many people find the notion of placing a value on human life to be distasteful and perhaps immoral. In particular, incorporating variation in the value of life used in benefit-cost analysis as a function of the age of the victims (beneficiaries), or as a function of the social proximity of the victims (beneficiaries) to the persons paying taxes to fund the project seems distasteful to many. If standard benefit-cost analysis were to adopt such age and social proximity adjustments, the political appeal of benefit-cost analysis as an analytical tool may be weakened. As a general matter, it is unclear whether including altruistic sentiments would lessen or enhance public confidence in the validity of benefit-cost analysis, and the challenges with estimating such altruism is sure to invite skeptical scrutiny.

The ultimate goal with this research is to produce evidence that would help scholars know whether altruistic sentiments are likely to be important in estimating the VSL. Given the magnitude of the VSL multiplier estimated here, I hope that this research serves as a catalyst for a new literature that re-conceptualizes the VSL from a social point of view.

Cited References

Aldy, J. E., & Viscusi, W. K. (2007). Age differences in the value of statistical life: Revealed preference evidence. *Review of Environmental Economics and Policy, 1*(2), 241-260.

Applebaum, B. (2011). As U.S. Agencies Put More Value on a Life, Businesses Fret. *The New York Times*, February 17.

Backstom, L. (2011). Anatomy of Facebook. Accessed on October 19, 2013 from https://www.facebook.com/notes/facebook-data-team/anatomy-of-facebook/10150388519243859.

Backstrom, L. Boldi, P. Rosa, M. Ugander, J., Vigna, S. (2011). Four Degrees of Separation. Accessed on October 19, 2013 from http://arxiv.org/abs/1111.4570.

Bergstrom, T. C. (I982). When is a man's life worth more than his human capital? In The *Value of Life and Safety*: Proceedings of a Conference held by the Geneva Association (ed. M. W. Jones-Lee), pp. 3-26. Amsterdam: North Holland.

Birchenall, J. A., & Soares, R. R. (2009). Altruism, fertility, and the value of children: Health policy evaluation and intergenerational welfare. *Journal of Public Economics*, *93*, 280–295.

Blomquist, G. C. (2004). Self-protection and averting behavior, values of statistical lives, and benefit cost analysis of environmental policy. *Review of Economics of the Household*, *2*(1), 89-110.

Cameron, T. A. (2010). Euthanizing the Value of a Statistical Life. *Review of Environmental Economics and Policy*, *4*(2), 161–178.

Carlin, P. S., & Sandy, R. (1991). Estimating the implicit value of a young child's life. *Southern Economic Journal*, *58*(1), 186-202.

Cropper, M., et al. (2007). *SAB advisory on EPA's issues in valuing mortality risk reduction* (EPA-SAB-08-001). Washington DC: U.S. Environmental Protection Agency Science Advisory Board.

Dickie, M., & Messman, V. L. (2004). Parental altruism and the value of avoiding acute illness: Are kids worth more than parents? *Journal of Environmental Economics and Management*, *48*(3), 1146-1174.

Graham, J. D. (2003, May 30). Benefit-cost methods and lifesaving rules (memorandum to the President's Management Council). Washington DC: Office of Information and Regulatory Affairs, Office of Management and Budget. Available: http://www.whitehouse.gov/omb/inforeg/pmc_benefit_cost_memo.pdf.

Gramlich, E. M. (1990). *A guide to benefit cost analysis*. Englewood Cliffs NJ: Prentice-Hall.

Engel, C. (2011). Dictator games: a meta study. *Experimental Economics*, 14(4), 583-610.

Hicks, John. (1939). "The Foundations of Welfare Economics." *The Economic Journal*, 49(196), pp. 696–712.

Jenkins, R. R., Owens, N., & Wiggins, L. B. (2001). Valuing reduced risks to children: The case of bicycle safety helmets. *Contemporary Economic Policy*, *19*(4), 397-408.

Jones-Lee, M. W. (1991). Altruism and the value of other people's safety. *Journal of Risk and Uncertainty, 4*(2), 213-219.

Jones-Lee, M. W. (1992). Paternalistic altruism and the value of statistical life. *Economic Journal, 102*(410), 80-90.

Kaldor, Nicholas. (1939). "Welfare Propositions in Economics and Interpersonal Comparisons of Utility." *The Economic Journal*, 49(195), pp. 549–552.

Kim, H. S. (2004). Measuring the value of statistical life in the U.S.A. by means of risk assessment of family automobile purchases. *Studies in Regional Science*, *34*(3), 225-236.

Krupnick, A. (2007). Mortality-risk valuation and age: Stated preference evidence. *Review of Environmental Economics and Policy*, *1*(2), 261-282.

Liu, J.-T., Hammitt, J. K., Wang, J.-D., & Liu, J.-L. (2000). Mother's willingness to pay for her own and her child's health: A contingent valuation survey in Taiwan. *Health Economics, 9*(4), 319–326.

Mrozek, J.R., & Taylor, L.O. (2002). What Determines the Value of Life? A Meta-Analysis," *Journal of Policy Analysis and Management*, *21*, 253-270.

National Academy of Sciences Committee on Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure. (2008). *Estimating mortality risk reduction and economic benefits from controlling ozone air pollution*. Washington DC: National Academies Press.

Needleman, L. (I976). Valuing other people's lives. *Manchester School*, *44,* pp. 309-42.

Rampell, C. (2011). American Migration Reaches Record Low. The New York Times, November 15.

Ugander, J. Karrer, B. Backstrom, L. Marlow, C. (2011). The Anatomy of the Facebook Social Graph, Accessed on October 19, 2013 from http://arxiv.org/abs/1111.4503.

Viscusi, W. K., & Aldy, J. E. (2003). The value of a statistical life: A critical review of market estimates throughout the world. *Journal of Risk and Uncertainty*, *27*(1), 5-76.

Uncited References

Aldy, J. E., & Viscusi, W. K. (2008). Adjusting the Value of a Statistical Life for Age and Cohort Effects. *Review of Economics and Statistics*, *90*(3), 573-581.

Andersson, H., & Lindberg, G. (2009). Benevolence and the value of road safety. *Accident Analysis and Prevention*, 41, 286–293.

Alberini, A., Cropper, M., Krupnick, A., & Simon, N. (2004). Does the value of a statistical life vary with age and health status? Evidence from the U.S. and Canada. *Journal of Environmental Economics and Management*, *48*(1), 769-792.

Atkinson, S.E., Halvorsen, R. (1990). The Valuation of Risks to Life: Evidence from the Market for Automobiles. *Review of Economics and Statistics*, *72*(1), 133-36.

Baker, R., Chilton, S., Jones-Lee, M., & Metcalf, H. (2008). Valuing lives equally: Defensible premise or unwarranted compromise? *Journal of Risk and Uncertainty*, *36*, 125–138.

Bruce, N., & Halvorsen, R. (2007). The Marginal Willingness to Pay for Longevity: A Better Way to Value Changes in Mortality Hazard. *Research in Law and Economics*, *23*, 273-299.

Carson, R. T., & Hanemann, W.M. (2005). Contingent Valuation. *Handbook of Environmental Economics*, Volume 2. Edited by K.-G. Mäler and J.R. Vincent, 821-936.

Croson, R.T.A. (2007).Theories of Commitment, Altruism and Reciprocity: Evidence From Linear Public Goods Games. *Economic Inquiry*, *45*(2), 199–216.

Dockins, C., Jenkins, R. R., Owens, N., Simon, N. B., & Wiggins, L. B. (2002). Valuation of childhood risk reduction: The importance of age, risk preferences and perspective. *Risk Analysis*, *22*(2), 335-346.

Hammitt, J. K., & Treich, N. (2007). Statistical vs. identified lives in benefit-cost analysis. *Journal of Risk and Uncertainty*, *35*(1), 45-66.

Ireland, T. R., & Ward, J. O. (1994).Valuing the life of a child: Broadening the investment approach. *Journal of Forensic Economics*, *7*(2), 179-191.

Kochi, I., Hubbell, B., & Kramer, R. (2006). An empirical Bayes approach to combining and comparing estimates of the value of a statistical life for environmental policy analysis. *Environmental and Resource Economics*, *34*(3), 385-406.

Robinson, L. A. (2007). How U.S. government agencies value mortality risk reductions. *Review of Environmental Economics and Policy*, 1(2), 283-299.

Shogren, J. F. (2001). Children and the environment: Valuing indirect effects on a child's life chances. *Contemporary Economic Policy*, *19*(4), 382-396.

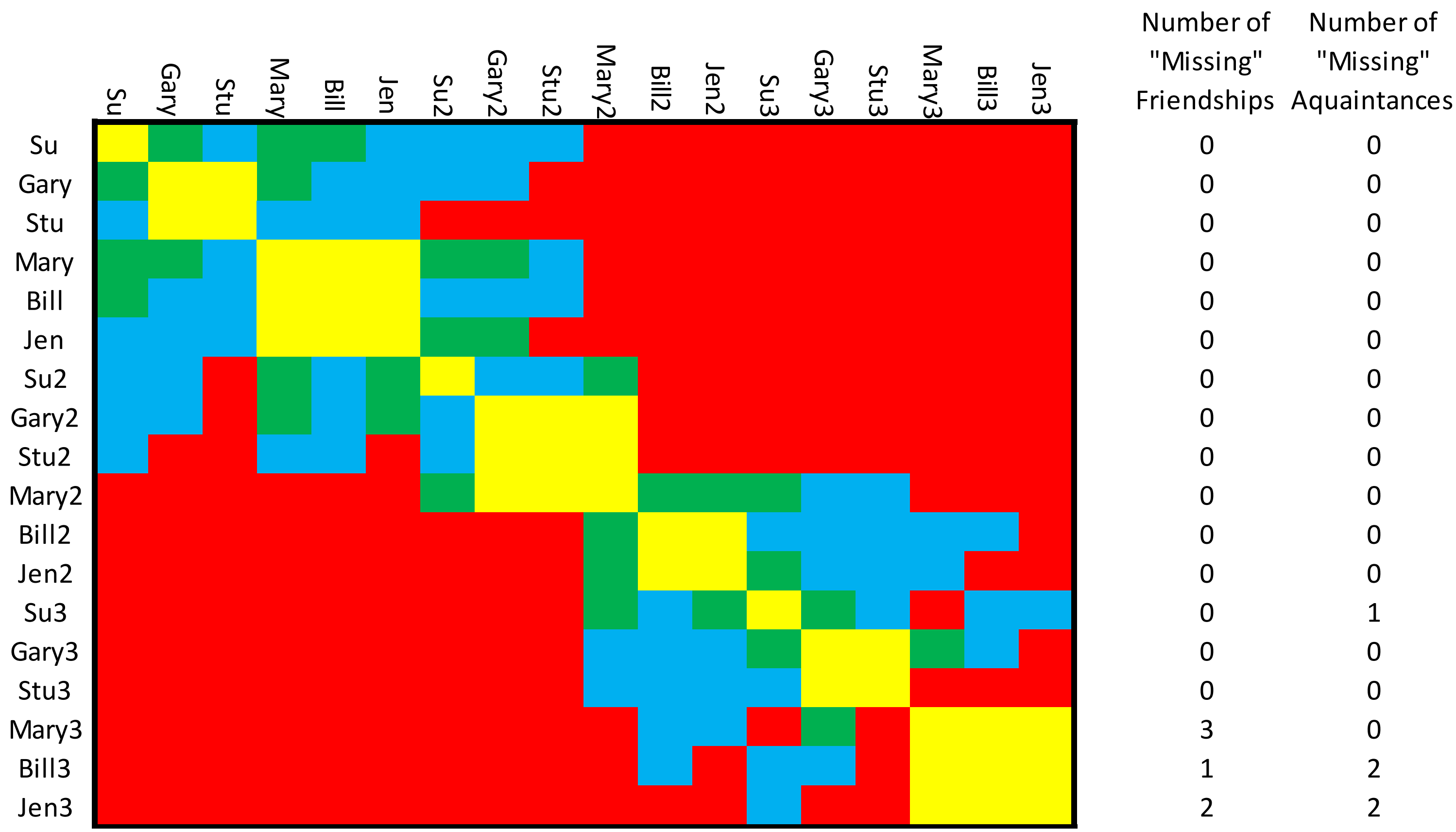
Viscusi,W.K. (1993). The value of risks to life and health. *Journal of Economics Literature*, *31*, 1912–1946.

Viscusi,W.K., Magat,W.A., & Forrest, A. (1988). Altruistic and private valuations of risk reduction. *Journal of Policy Analysis and Management*, *7*(2), 227–245.

Table 1: Hypothetical Respondent Data Used in Figures 1 & 2

Respondent's Name	Respondent's Survey Responses: Number of Family Members (incl. Self)	Number of Friends	Number of Acquaintances
Su	1	3	5
Gary	2	2	4
Stu	2	0	4
Mary	3	4	2
Bill	3	1	5
Jen	3	2	3

Figure 1: Matrix of Relationships Using the "Tight" Approach and Based on Hypothetical Respondent Data in Table 1



Note: Yellow cell = Family Member, Green cell = Friend, Blue cell = Acquaintance, and Red cell = Stranger

Figure 2: Matrix of Relationships Using the "Loose" Approach and Based on Hypothetical Respondent Data in Table 1

	Number of "Missing" Friendships	Number of "Missing" Aquaintances
Su	0	0
Gary	0	0
Stu	0	0
Mary	1	0
Bill	0	1
Jen	0	1
Su2	0	0
Gary2	0	0
Stu2	0	0
Mary2	0	0
Bill2	0	0
Jen2	0	0
Su3	0	1
Gary3	0	0
Stu3	0	0
Mary3	2	0
Bill3	0	0
Jen3	0	0

Note: Yellow cell = Family Member, Green cell = Friend, Blue cell = Acquaintance, and Red cell = Stranger

Figure 3: Mean Responses to Safety Altruism Questions, by Age-Relationship of Other Person

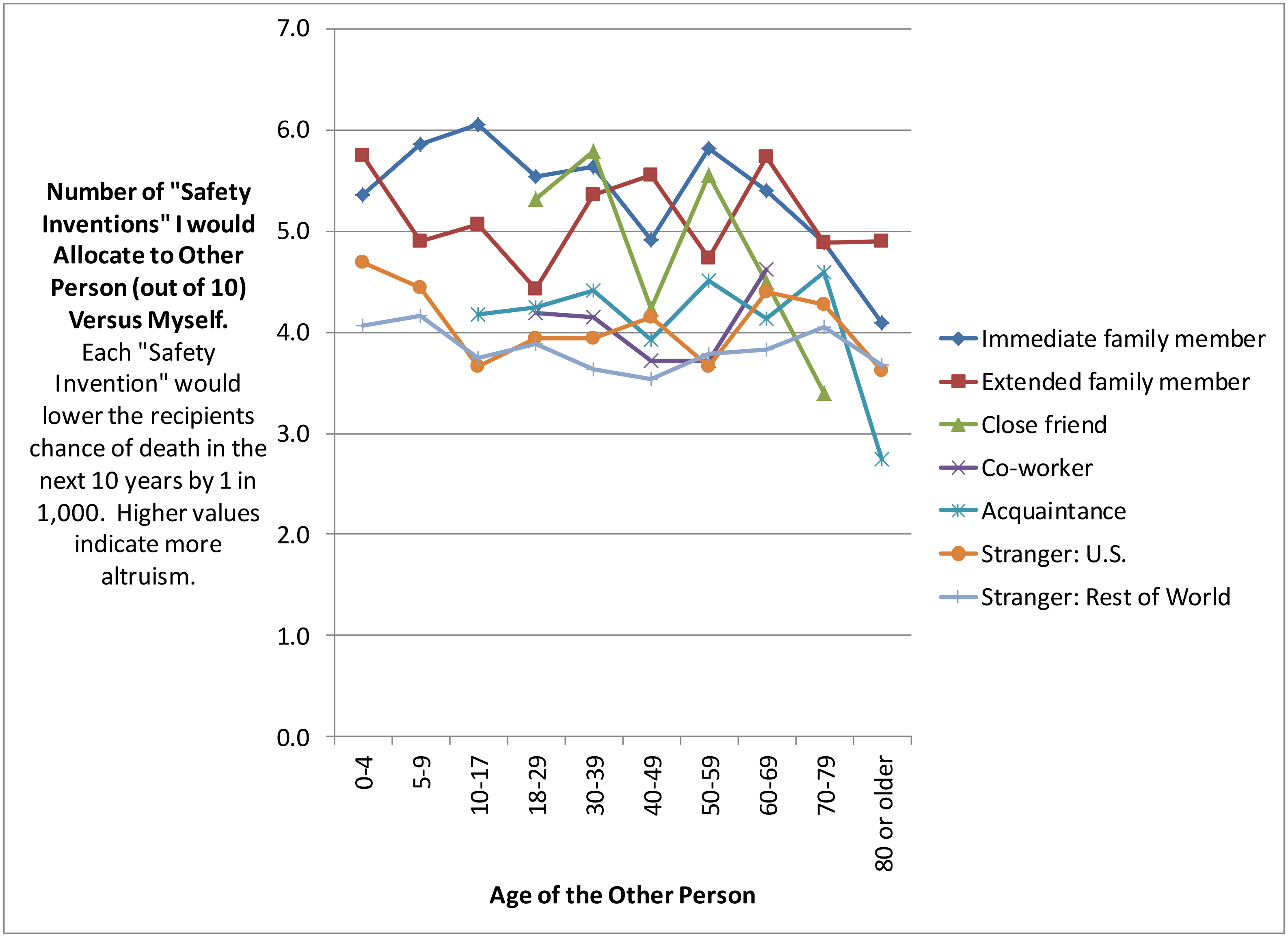


Figure 4: Mean Responses to Wealth Altruism Questions, by Age-Relationship of Other Person

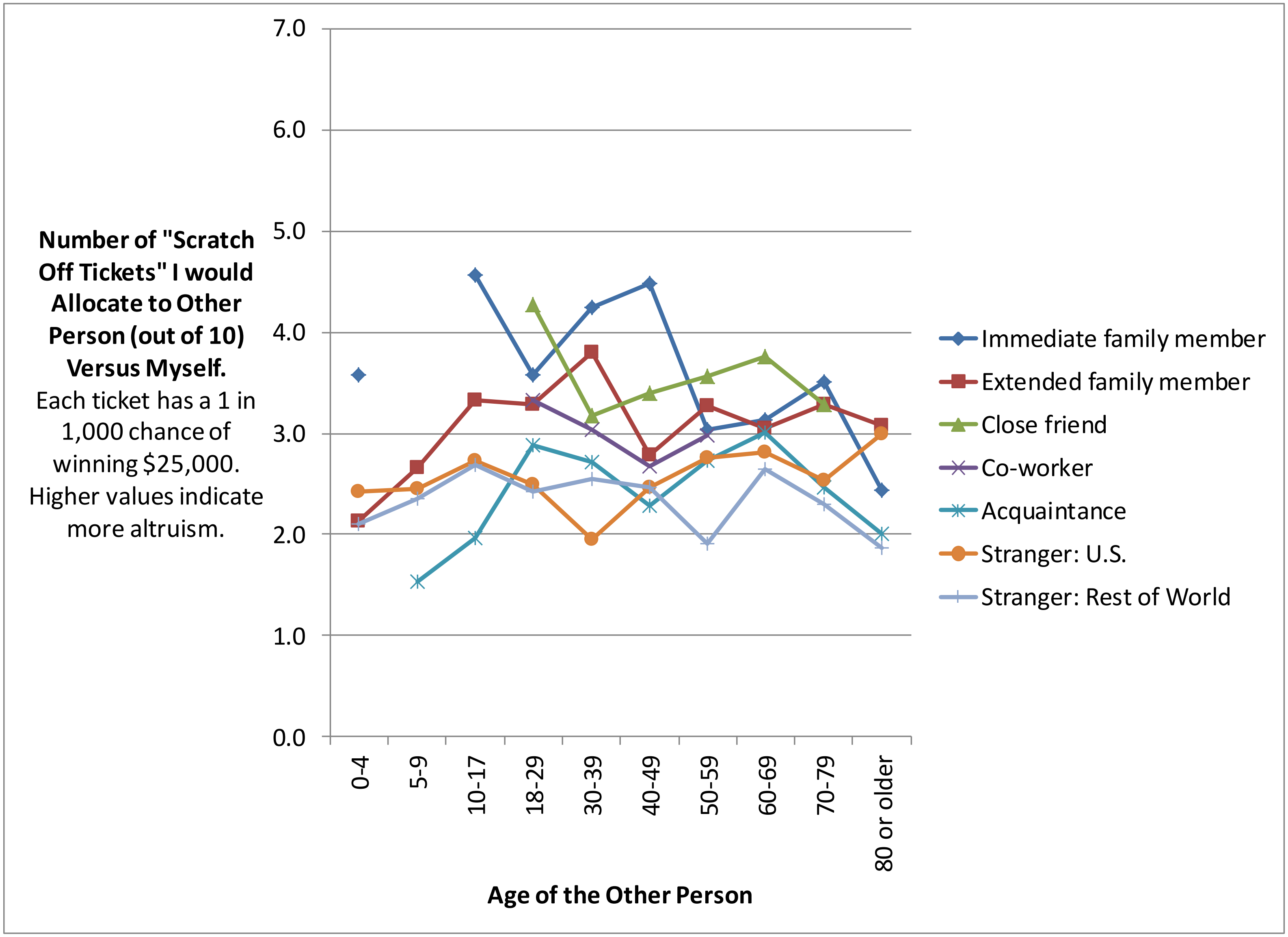
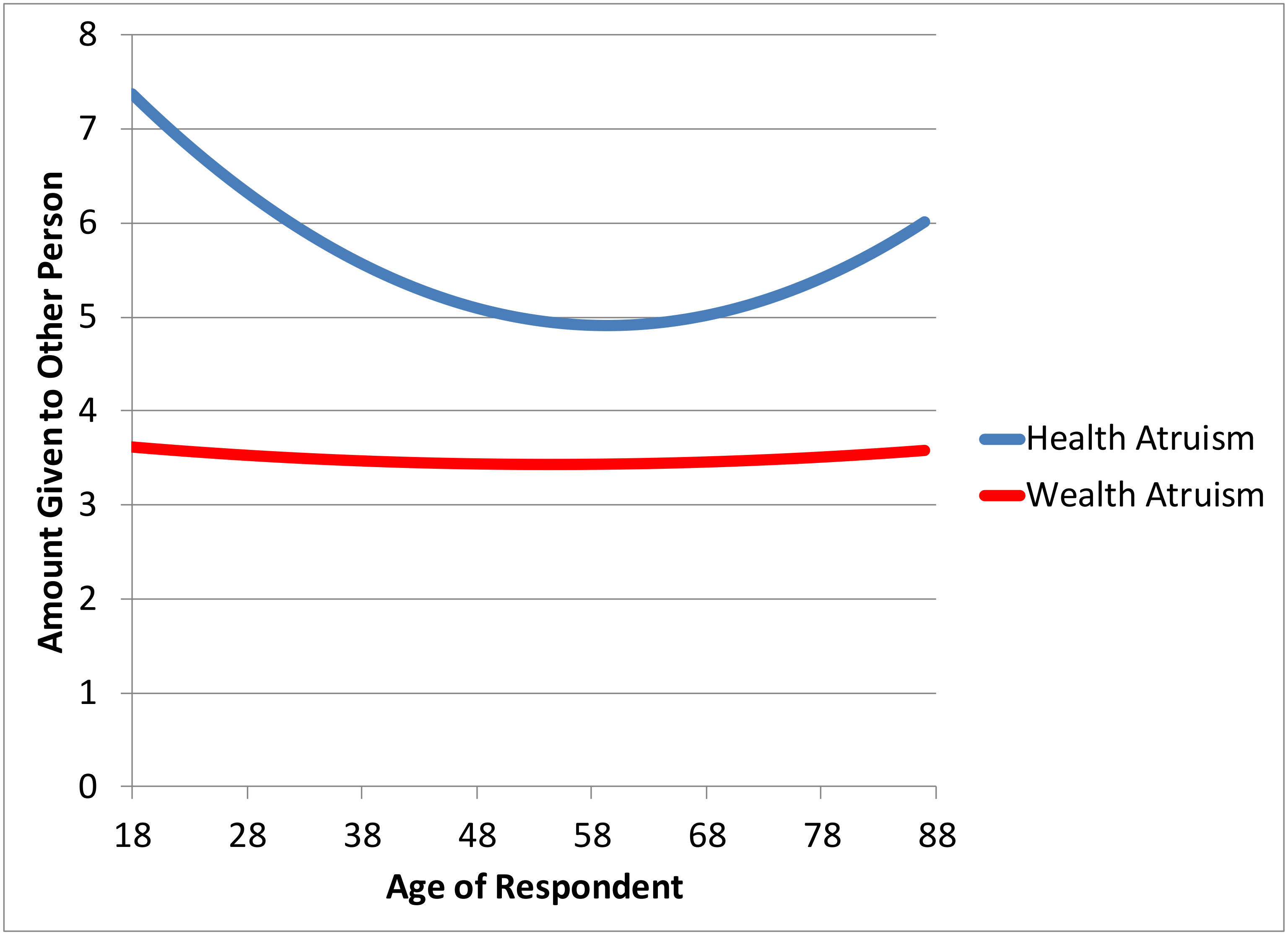


Table 2: Predictors of the Respondent's Level of Safety and Wealth Altruism

	Safety			Wealth		
	Coef.	(s.e.)	Sig.	Coef.	(s.e.)	Sig.
Characteristics of the Other Person						
Relationship (relative to immediate family member):						
Extended Family Member	-0.36	(0.22)	*	-0.65	(0.18)	***
Close Friend	-0.24	(0.29)		-0.19	(0.23)	
Co-Worker	-1.29	(0.31)	***	-0.81	(0.33)	**
Acquaintance	-1.03	(0.27)	***	-1.19	(0.22)	***
Stranger: U.S.	-1.41	(0.23)	***	-1.13	(0.21)	***
Stranger: Rest of World	-1.66	(0.23)	***	-1.40	(0.20)	***
Age of other person (relative to age 0-4):						
5-9	-0.12	(0.23)		0.13	(0.24)	
10-17	-0.37	(0.31)		0.53	(0.30)	*
18-29	-0.61	(0.25)	***	0.46	(0.23)	**
30-39	-0.16	(0.29)		0.34	(0.30)	
40-49	-0.43	(0.29)		0.34	(0.30)	
50-59	-0.29	(0.29)		0.34	(0.27)	
60-69	0.00	(0.25)		0.48	(0.30)	
70-79	-0.20	(0.29)		0.33	(0.29)	
80 and older	-0.57	(0.26)	**	0.31	(0.28)	
Characteristics of the Respondent						
Female	-0.08	(0.29)		0.09	(0.27)	
Age	-0.17	(0.05)	***	-0.02	(0.05)	
Age^2	0.0014	(0.0006)	***	0.0001	(0.0005)	
Relative to those who reside in birth state:						
Live in Different State from Birth, Within 500 Miles	-0.51	(0.35)		-0.46	(0.32)	
Live in Different State from Birth, 500-999 Miles	-0.60	(0.55)		-0.93	(0.43)	**
Live in Different State from Birth, 1000+ Miles	-0.67	(0.43)		-0.61	(0.35)	*
Born Outside U.S.	-0.59	(0.60)		-0.59	(0.52)	
Framing Effects						
Asked safety altruism questions first	0.47	(0.42)		0.27	(0.39)	
Other person placed on left (before the respondent)	0.03	(0.41)		-0.11	(0.31)	
Interaction of above framing issues	0.70	(0.58)		0.39	(0.54)	
Constant	9.99	(1.17)		3.85	(1.09)	***
P-Value for Test of Joint Significance of:						
Relationship		0.0%	***		0.0%	***
Age of other person		5.0%	*		38.4%	
Age and Age^2		0.0%	***		93.5%	
Live in Different State from Birth or Born Outside U.S.		22.0%			11.9%	
Framing Effects		1.6%	**		33.2%	

Note: Robust standard errors are used, clustered by survey respondent. Two-tailed statistical significance at the 1%, 5%, and 10% levels are indicated, respectively, by ***, **, and *.

Figure 5: Altruism as a Function of the Age of Respondent



Note: Predicted based on Age and Age^2 coefficients in the regression results in Table 2 with all other covariates set to zero.

Table 3: Estimates of the Ratio of Mean Safety Altruism to Mean Wealth Altruism

	(1) Base Assumptions	(2) Base Assumptions except "Tight" Social Relations	(3) Base Assumptions except All Persons Reside >1,000 Miles From Birth State	(4) Base Assumptions except Strangers are from Other Countries	(5) Base Assumptions except Matrix Size Set to 1,250 × 1,250	(6) Base Assumptions except Matrix Size Set to 1,875 × 1,875
Panel A: Including All Persons						
Public Policy Has Uniform Effects on Public Safety:	2.2 (0.2) ***	2.2 (0.2) ***	2.3 (0.3) ***	2.3 (0.2) ***		
Public Policy Only Affects the Safety of Those Age:						
0 to 4	3.0 (0.8) ***	3.0 (0.8) **	3.2 (1.1) *	3.1 (0.9) **		
5 to 9	2.6 (0.7) **	2.6 (0.7) **	2.8 (0.8) **	2.7 (0.6) ***		
10 to 17	2.0 (0.5) *	2.0 (0.5) **	2.0 (0.8)	2.0 (0.4) **		
18 to 29	1.9 (0.4) **	1.9 (0.5) *	1.9 (0.6)	1.9 (0.4) **		
30 to 39	2.4 (0.5) ***	2.4 (0.7) **	2.5 (0.9)	2.4 (0.6) **	Not Yet Available	
40 to 49	2.1 (0.4) ***	2.1 (0.5) **	2.2 (0.6) **	2.2 (0.6) *		
50 to 59	2.2 (0.5) **	2.2 (0.7) *	2.3 (0.7) **	2.3 (0.5) ***		
60 to 69	2.4 (0.5) ***	2.4 (0.6) **	2.4 (0.8) *	2.4 (0.6) ***		
70 to 79	2.3 (0.4) ***	2.3 (0.6) **	2.4 (0.6) **	2.4 (0.6) **		
80 and above	2.0 (0.5) **	2.0 (0.7)	2.1 (0.7)	2.1 (0.6) *		
Panel B: Excluding Valuations by Minor Children						
Public Policy Has Uniform Effects on Public Safety:	1.9 (0.1) ***	1.9 (0.1) ***	1.9 (0.2) ***	1.9 (0.1) ***		
Public Policy Only Affects the Safety of Those Age:						
0 to 4	2.5 (0.6) ***	2.5 (0.6) **	2.7 (0.9) *	2.6 (0.7) **		
5 to 9	2.2 (0.5) **	2.2 (0.5) **	2.3 (0.6) **	2.3 (0.5) ***		
10 to 17	1.6 (0.4)	1.6 (0.4) *	1.7 (0.6)	1.7 (0.3) **		
18 to 29	1.6 (0.3) *	1.5 (0.3)	1.6 (0.4)	1.6 (0.3) *		
30 to 39	2.0 (0.3) ***	2.0 (0.5) **	2.1 (0.6) *	2.1 (0.4) ***	Not Yet Available	
40 to 49	1.8 (0.3) ***	1.8 (0.4) **	1.8 (0.4) **	1.8 (0.4) **		
50 to 59	1.9 (0.3) ***	1.9 (0.4) *	2.0 (0.5) **	1.9 (0.3) ***		
60 to 69	2.0 (0.3) ***	2.0 (0.4) **	2.1 (0.6) *	2.0 (0.4) ***		
70 to 79	2.0 (0.3) ***	1.9 (0.4) **	2.0 (0.5) **	2.0 (0.4) **		
80 and above	1.7 (0.3) **	1.7 (0.5)	1.8 (0.5) *	1.8 (0.4) **		

Note: Standard errors are shown in parentheses. ***, **, and * denote that the ratio is significantly below or above 1.0 using a two-tailed test at, respectively, the 1%, 5%, and 10% levels.

Table 4: Estimates of the VSL Multiplier

	(1) Base Assumptions	(2) Base Assumptions except "Tight" Social Relations	(3) Base Assumptions except All Persons Reside >1,000 Miles From Birth State	(4) Base Assumptions except Strangers are from Other Countries	(5) Base Assumptions except Matrix Size Set to 1,250 × 1,250	(6) Base Assumptions except Matrix Size Set to 1,875 × 1,875
Public Policy Has Uniform Effects on Public Safety:	7.3 (3.1) **	4.7 (3.1)	1.1 (2.9)	4.0 (2.4)		
Public Policy Only Affects the Safety of Those Age:						
0 to 4	7.6 (3.1) **	5.7 (3.2)	2.5 (3.2)	4.1 (2.5)	Not Yet Available	
5 to 9	7.6 (3.4) *	5.9 (3.4)	2.1 (2.8)	3.7 (2.9)		
10 to 17	8.7 (3.4) **	4.6 (3.3)	1.3 (3.1)	5.4 (2.7)		
18 to 29	8.3 (3.8) *	4.4 (3.8)	2.6 (3.2)	5.5 (2.4) *		
30 to 39	7.3 (3.7) *	5.3 (3.5)	2.4 (3.1)	4.0 (2.0)		
40 to 49	9.9 (3.5) **	5.2 (3.5)	2.0 (3.5)	5.6 (2.3) **		
50 to 59	10.4 (3.7) **	5.0 (3.7)	2.4 (3.1)	5.2 (2.5) *		
60 to 69	10.9 (2.8) ***	7.0 (2.8) **	1.1 (3.0)	4.9 (1.7) **		
70 to 79	7.6 (3.4) **	6.2 (3.4)	2.2 (2.9)	6.0 (1.1) ***		
80 and above	6.0 (3.4)	3.1 (3.3)	1.9 (3.2)	6.7 (2.0) ***		

Note: Standard errors are shown in parentheses. ***, **, and * denote that the VSL Multiplier is significantly below or above 1.0 using a two-tailed test at, respectively, the 1%, 5%, and 10% levels.

Note: Standard errors are shown in parentheses. ***, **, and * denote that the VSL Multiplier is significantly below or above 1.0 using a two-tailed test at, respectively, the 1%, 5%, and 10% levels.

Appendix A: Mathematical Derivation of the Multiplier

The following construction of the social planner's problem mirrors the construction by Jones-Lee (1992), and is discussed in greater detail in that paper. I am assuming a social planner wants to maximize a utilitarian social welfare function (i.e., that the planner seeks to maximize the sum of individual utilities).[18] Each individual has a utility function ($u_i(.)$) that takes into consideration the survival probabilities of each person (π_j) and the wealth (w_j) of each person net of taxes (t_j) used to pay for public projects that will increase survival probabilities. The sum of the taxes collected must be equal to the cost of all public safety projects (s). The utilitarian social planner selects the amount of taxes collected and the amount spent on public safety projects such that social welfare is maximized. It is assumed that wealth is exogenous and not affected by spending on public safety.

Two-Person World

To illustrate the problem mathematically, I begin with a two-person world.

$max_{s,t_i} \sum_{i=1}^{2} u_i(\pi_1, w_1 - t_1, \pi_2, w_2 - t_2)$ subject to $s = \sum_{i=1}^{2} t_i$

$$\max_{s,t_i,\lambda} L = \sum_{i=1}^{2} u_i(\pi_1, w_1 - t_1, \pi_2, w_2 - t_2) - \lambda(s - \sum_{i=1}^{2} t_i)$$

First-order conditions:

(1) $\frac{\partial L}{\partial s} = 0 \rightarrow \sum_{i=1}^{2} \sum_{j=1}^{2} u_{j\pi_i} \frac{\partial \pi_i}{\partial s} = \lambda$ NOTE: $u_{j\pi_i} = \frac{\partial u_j}{\partial \pi_i}$

(2) $\frac{\partial L}{\partial t_i} = 0 \rightarrow \sum_{j=1}^{2} u_{jw_i} = \lambda, \quad i = 1,2$ NOTE: $u_{jw_i} = \frac{\partial u_j}{\partial w_i}$

(3) $\frac{\partial L}{\partial \lambda} = 0 \rightarrow s = \sum_{i=1}^{2} t_i$

First-order condition (1) says that we should spend on safety until the marginal benefit from a dollar spent on safety (left-hand side) = marginal utility of a dollar (lambda).

[18] I am not including the distributional weights that Jones-Lee (1992) includes. These drop out of Jones-Lee's calculation.

Rewrite first-order conditions (2) in matrix notation:

(4) $$\begin{bmatrix} 1 & \frac{u_{2w_1}}{u_{2w_2}} \\ \frac{u_{1w_2}}{u_{1w_1}} & 1 \end{bmatrix} \begin{bmatrix} u_{1w_1} \\ u_{2w_2} \end{bmatrix} = \begin{bmatrix} 1 & n_{21} \\ n_{12} & 1 \end{bmatrix} \begin{bmatrix} u_{1w_1} \\ u_{2w_2} \end{bmatrix} = \begin{bmatrix} \lambda \\ \lambda \end{bmatrix} \quad \text{NOTE: } n_{ji} = \frac{u_{jw_i}}{u_{jw_j}}$$

Now, invert the $\begin{bmatrix} 1 & n_{21} \\ n_{12} & 1 \end{bmatrix}$matrix, multiply both sides by the inverted matrix, and solve for u_{jw_i}.

(5) $$\begin{bmatrix} \frac{1}{1-n_{21}n_{12}} & \frac{-n_{12}}{1-n_{21}n_{12}} \\ \frac{-n_{21}}{1-n_{21}n_{12}} & \frac{1}{1-n_{21}n_{12}} \end{bmatrix} \begin{bmatrix} 1 & n_{21} \\ n_{12} & 1 \end{bmatrix} \begin{bmatrix} u_{1w_1} \\ u_{2w_2} \end{bmatrix} = \begin{bmatrix} \frac{1}{1-n_{21}n_{12}} & \frac{-n_{12}}{1-n_{21}n_{12}} \\ \frac{-n_{21}}{1-n_{21}n_{12}} & \frac{1}{1-n_{21}n_{12}} \end{bmatrix} \begin{bmatrix} \lambda \\ \lambda \end{bmatrix}$$

(6) $$\begin{bmatrix} u_{1w_1} \\ u_{2w_2} \end{bmatrix} = \begin{bmatrix} \frac{1}{1-n_{21}n_{12}} & \frac{-n_{12}}{1-n_{21}n_{12}} \\ \frac{-n_{21}}{1-n_{21}n_{12}} & \frac{1}{1-n_{21}n_{12}} \end{bmatrix} \begin{bmatrix} \lambda \\ \lambda \end{bmatrix} = \begin{bmatrix} \lambda \frac{1-n_{12}}{1-n_{21}n_{12}} \\ \lambda \frac{1-n_{21}}{1-n_{21}n_{12}} \end{bmatrix}$$

Expand FOC (1):

(7) $$u_{1\pi_1} \frac{\partial \pi_1}{\partial s} + u_{2\pi_1} \frac{\partial \pi_1}{\partial s} + u_{1\pi_2} \frac{\partial \pi_2}{\partial s} + u_{2\pi_2} \frac{\partial \pi_2}{\partial s} = \lambda$$

Use (6) in (7) by multiplying each term as follows:

(8) $$\lambda \frac{1-n_{12}}{1-n_{21}n_{12}} \frac{u_{1\pi_1}}{u_{1w_1}} \frac{\partial \pi_1}{\partial s} + \lambda \frac{1-n_{21}}{1-n_{21}n_{12}} \frac{u_{2\pi_1}}{u_{2w_2}} \frac{\partial \pi_1}{\partial s} + \lambda \frac{1-n_{12}}{1-n_{21}n_{12}} \frac{u_{1\pi_2}}{u_{1w_1}} \frac{\partial \pi_2}{\partial s} + \lambda \frac{1-n_{21}}{1-n_{21}n_{12}} \frac{u_{2\pi_2}}{u_{2w_2}} \frac{\partial \pi_2}{\partial s} = \lambda$$

Divide both sides by λ.

(9) $$\frac{1-n_{12}}{1-n_{21}n_{12}} \frac{u_{1\pi_1}}{u_{1w_1}} \frac{\partial \pi_1}{\partial s} + \frac{1-n_{21}}{1-n_{21}n_{12}} \frac{u_{2\pi_1}}{u_{2w_2}} \frac{\partial \pi_1}{\partial s} + \frac{1-n_{12}}{1-n_{21}n_{12}} \frac{u_{1\pi_2}}{u_{1w_1}} \frac{\partial \pi_2}{\partial s} + \frac{1-n_{21}}{1-n_{21}n_{12}} \frac{u_{2\pi_2}}{u_{2w_2}} \frac{\partial \pi_2}{\partial s} = 1$$

Denote $m_{ji} = \frac{u_{j\pi_i}}{u_{jw_j}}$.

(10) $$\frac{1-n_{12}}{1-n_{21}n_{12}} m_{11} \frac{\partial \pi_1}{\partial s} + \frac{1-n_{21}}{1-n_{21}n_{12}} m_{21} \frac{\partial \pi_1}{\partial s} + \frac{1-n_{12}}{1-n_{21}n_{12}} m_{12} \frac{\partial \pi_2}{\partial s} + \frac{1-n_{21}}{1-n_{21}n_{12}} m_{22} \frac{\partial \pi_2}{\partial s} = 1$$

(11) $$\frac{1-n_{12}}{1-n_{21}n_{12}} \left(m_{11} \frac{\partial \pi_1}{\partial s} + m_{12} \frac{\partial \pi_2}{\partial s} \right) + \frac{1-n_{21}}{1-n_{21}n_{12}} \left(m_{21} \frac{\partial \pi_1}{\partial s} + m_{22} \frac{\partial \pi_2}{\partial s} \right) = 1$$

Assume $m_{11} = m_{22} = m$ – i.e., a constant value of own life.

(12) $$m \left[\frac{1-n_{12}}{1-n_{21}n_{12}} \left(\frac{\partial \pi_1}{\partial s} + \frac{m_{12}}{m} \frac{\partial \pi_2}{\partial s} \right) + \frac{1-n_{21}}{1-n_{21}n_{12}} \left(\frac{m_{21}}{m} \frac{\partial \pi_1}{\partial s} + \frac{\partial \pi_2}{\partial s} \right) \right] = 1$$

Multiply both sides by $\frac{\partial s}{\sum_{i=1}^{2} \partial \pi_i}$, which is the marginal cost of saving one additional life.

(13) $$\frac{\partial s}{\sum_{i=1}^{2} \partial \pi_i} m \left[\frac{1-n_{12}}{1-n_{21}n_{12}}\left(\frac{\partial \pi_1}{\partial s} + \frac{m_{12}}{m}\frac{\partial \pi_2}{\partial s}\right) + \frac{1-n_{21}}{1-n_{21}n_{12}}\left(\frac{m_{21}}{m}\frac{\partial \pi_1}{\partial s} + \frac{\partial \pi_2}{\partial s}\right)\right] = \frac{\partial s}{\sum_{i=1}^{2} \partial \pi_i}$$

(14) $$m\left[\frac{1-n_{12}}{1-n_{21}n_{12}}\left(\frac{\frac{\partial \pi_1}{\partial s}}{\frac{\sum_{i=1}^{2} \partial \pi_i}{\partial s}} + \frac{m_{12}}{m}\frac{\frac{\partial \pi_2}{\partial s}}{\frac{\sum_{i=1}^{2} \partial \pi_i}{\partial s}}\right) + \frac{1-n_{21}}{1-n_{21}n_{12}}\left(\frac{m_{21}}{m}\frac{\frac{\partial \pi_1}{\partial s}}{\frac{\sum_{i=1}^{2} \partial \pi_i}{\partial s}} + \frac{\frac{\partial \pi_2}{\partial s}}{\frac{\sum_{i=1}^{2} \partial \pi_i}{\partial s}}\right)\right] = \frac{\partial s}{\sum_{i=1}^{2} \partial \pi_i}$$

Now, let $\sum_{i=1}^{2} \partial \pi_i = 1$. That is, one life is saved by the safety invention.

(15) $$m\left[\frac{1-n_{12}}{1-n_{21}n_{12}}\left(\frac{\frac{\partial \pi_1}{\partial s}}{\frac{1}{\partial s}} + \frac{m_{12}}{m}\frac{\frac{\partial \pi_2}{\partial s}}{\frac{1}{\partial s}}\right) + \frac{1-n_{21}}{1-n_{21}n_{12}}\left(\frac{m_{21}}{m}\frac{\frac{\partial \pi_1}{\partial s}}{\frac{1}{\partial s}} + \frac{\frac{\partial \pi_2}{\partial s}}{\frac{1}{\partial s}}\right)\right] = \frac{\partial s}{\sum_{i=1}^{2} \partial \pi_i}$$

(16) $$m\left[\frac{1-n_{12}}{1-n_{21}n_{12}}\left(\partial \pi_1 + \frac{m_{12}}{m}\partial \pi_2\right) + \frac{1-n_{21}}{1-n_{21}n_{12}}\left(\frac{m_{21}}{m}\partial \pi_1 + \partial \pi_2\right)\right] = \frac{\partial s}{\sum_{i=1}^{2} \partial \pi_i}$$

Thus, the VSL multiplier is the term in brackets [].

Three-Person World

I now illustrate the problem using a three-person world.

$max_{s,t_i} \sum_{i=1}^{3} u_i(\pi_1, w_1 - t_1, \pi_2, w_2 - t_2, \pi_3, w_3 - t_3)$ subject to $s = \sum_{i=1}^{3} t_i$

$$\max_{s,t_i,\lambda} L = \sum_{i=1}^{3} u_i(\pi_1, w_1 - t_1, \pi_2, w_2 - t_2, \pi_3, w_3 - t_3) - \lambda(s - \sum_{i=1}^{3} t_i)$$

First-order conditions:

(1) $\frac{\partial L}{\partial s} = 0 \rightarrow \sum_{i=1}^{3}\sum_{j=1}^{3} u_{j\pi_i}\frac{\partial \pi_i}{\partial s} = \lambda$ NOTE: $u_{j\pi_i} = \frac{\partial u_j}{\partial \pi_i}$

(2) $\frac{\partial L}{\partial t_i} = 0 \rightarrow \sum_{j=1}^{3} u_{jw_i} = \lambda, \quad i = 1,2,3$ NOTE: $u_{jw_i} = \frac{\partial u_j}{\partial w_i}$

(3) $\frac{\partial L}{\partial \lambda} = 0 \rightarrow s = \sum_{i=1}^{2} t_i$

Rewrite first-order conditions (2) in matrix notation:

(4) $$\begin{bmatrix} 1 & \frac{u_{2w_1}}{u_{2w_2}} & \frac{u_{3w_1}}{u_{3w_3}} \\ \frac{u_{1w_2}}{u_{1w_1}} & 1 & \frac{u_{3w_2}}{u_{3w_3}} \\ \frac{u_{1w_3}}{u_{1w_1}} & \frac{u_{2w_3}}{u_{2w_2}} & 1 \end{bmatrix}\begin{bmatrix} u_{1w_1} \\ u_{2w_2} \\ u_{3w_3} \end{bmatrix} = \begin{bmatrix} 1 & n_{21} & n_{31} \\ n_{12} & 1 & n_{32} \\ n_{13} & n_{23} & 1 \end{bmatrix}\begin{bmatrix} u_{1w_1} \\ u_{2w_2} \\ u_{3w_3} \end{bmatrix} = \begin{bmatrix} \lambda \\ \lambda \\ \lambda \end{bmatrix}$$ NOTE: $n_{ji} = \frac{u_{jw_i}}{u_{jw_j}}$

Now, invert the $\begin{bmatrix} 1 & n_{21} & n_{31} \\ n_{12} & 1 & n_{32} \\ n_{13} & n_{23} & 1 \end{bmatrix}$ matrix, multiply both sides by the inverted matrix, and solve for u_{jw_i}.

(5) $$\begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} 1 & n_{21} & n_{31} \\ n_{12} & 1 & n_{32} \\ n_{13} & n_{23} & 1 \end{bmatrix} \begin{bmatrix} u_{1w_1} \\ u_{2w_2} \\ u_{3w_3} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} \lambda \\ \lambda \\ \lambda \end{bmatrix}$$

(6) $$\begin{bmatrix} u_{1w_1} \\ u_{2w_2} \\ u_{3w_3} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} \lambda \\ \lambda \\ \lambda \end{bmatrix} = \begin{bmatrix} \lambda \sum_{i=1}^{3} A_{1i} \\ \lambda \sum_{i=1}^{3} A_{2i} \\ \lambda \sum_{i=1}^{3} A_{3i} \end{bmatrix}$$

Expand FOC (1):

(7) $$u_{1\pi_1} \tfrac{\partial \pi_1}{\partial s} + u_{2\pi_1} \tfrac{\partial \pi_1}{\partial s} + u_{3\pi_1} \tfrac{\partial \pi_1}{\partial s} + u_{1\pi_2} \tfrac{\partial \pi_2}{\partial s} + u_{2\pi_2} \tfrac{\partial \pi_2}{\partial s} + u_{3\pi_2} \tfrac{\partial \pi_2}{\partial s} + u_{1\pi_3} \tfrac{\partial \pi_3}{\partial s} + u_{2\pi_3} \tfrac{\partial \pi_3}{\partial s} + u_{3\pi_3} \tfrac{\partial \pi_3}{\partial s} = \lambda$$

Use (6) in (7) by multiplying each term as follows:

(8)

$$\lambda \sum_{i=1}^{3} A_{1i} \frac{u_{1\pi_1}}{u_{1w_1}} \frac{\partial \pi_1}{\partial s} + \lambda \sum_{i=1}^{3} A_{2i} \frac{u_{2\pi_1}}{u_{2w_2}} \frac{\partial \pi_1}{\partial s} + \lambda \sum_{i=1}^{3} A_{3i} \frac{u_{3\pi_1}}{u_{3w_3}} \frac{\partial \pi_1}{\partial s}_1 + \lambda \sum_{i=1}^{3} A_{1i} \frac{u_{1\pi_2}}{u_{1w_1}} \frac{\partial \pi_2}{\partial s} + \lambda \sum_{i=1}^{3} A_{2i} \frac{u_{2\pi_2}}{u_{2w_2}} \frac{\partial \pi_2}{\partial s} + \lambda \sum_{i=1}^{3} A_{3i} \frac{u_{3\pi_2}}{u_{3w_3}} \frac{\partial \pi_2}{\partial s} + \lambda \sum_{i=1}^{3} A_{1i} \frac{u_{1\pi_3}}{u_{1w_1}} \frac{\partial \pi_3}{\partial s} + \lambda \sum_{i=1}^{3} A_{2i} \frac{u_{2\pi_3}}{u_{2w_2}} \frac{\partial \pi_3}{\partial s} + \lambda \sum_{i=1}^{3} A_{3i} \frac{u_{3\pi_3}}{u_{3w_3}} \frac{\partial \pi_3}{\partial s} = \lambda$$

Divide both sides by λ.

(9)

$$\sum_{i=1}^{3} A_{1i} \frac{u_{1\pi_1}}{u_{1w_1}} \frac{\partial \pi_1}{\partial s} + \sum_{i=1}^{3} A_{2i} \frac{u_{2\pi_1}}{u_{2w_2}} \frac{\partial \pi_1}{\partial s} + \sum_{i=1}^{3} A_{3i} \frac{u_{3\pi_1}}{u_{3w_3}} \frac{\partial \pi_1}{\partial s}_1 + \sum_{i=1}^{3} A_{1i} \frac{u_{1\pi_2}}{u_{1w_1}} \frac{\partial \pi_2}{\partial s} + \sum_{i=1}^{3} A_{2i} \frac{u_{2\pi_2}}{u_{2w_2}} \frac{\partial \pi_2}{\partial s} + \sum_{i=1}^{3} A_{3i} \frac{u_{3\pi_2}}{u_{3w_3}} \frac{\partial \pi_2}{\partial s} + \sum_{i=1}^{3} A_{1i} \frac{u_{1\pi_3}}{u_{1w_1}} \frac{\partial \pi_3}{\partial s} + \sum_{i=1}^{3} A_{2i} \frac{u_{2\pi_3}}{u_{2w_2}} \frac{\partial \pi_3}{\partial s} + \sum_{i=1}^{3} A_{3i} \frac{u_{3\pi_3}}{u_{3w_3}} \frac{\partial \pi_3}{\partial s} = 1$$

Denote $m_{ji} = \frac{u_{j\pi_i}}{u_{jw_j}}$

(10)

$$\sum_{i=1}^{3} A_{1i}\, m_{11} \frac{\partial \pi_1}{\partial s} + \sum_{i=1}^{3} A_{2i}\, m_{21} \frac{\partial \pi_1}{\partial s} + \sum_{i=1}^{3} A_{3i}\, m_{31} \frac{\partial \pi_1}{\partial s}{}_1 + \sum_{i=1}^{3} A_{1i}\, m_{12} \frac{\partial \pi_2}{\partial s} + \sum_{i=1}^{3} A_{2i}\, m_{22} \frac{\partial \pi_2}{\partial s} + \sum_{i=1}^{3} A_{3i}\, m_{32} \frac{\partial \pi_2}{\partial s} + \sum_{i=1}^{3} A_{1i}\, m_{13} \frac{\partial \pi_3}{\partial s} + \sum_{i=1}^{3} A_{2i}\, m_{23} \frac{\partial \pi_3}{\partial s} + \sum_{i=1}^{3} A_{3i}\, m_{33} \frac{\partial \pi_3}{\partial s} = 1$$

Group terms with the same coefficient from inverted matrix.

(11) $$\sum_{i=1}^{3} A_{1i} \left(m_{11} \frac{\partial \pi_1}{\partial s} + m_{12} \frac{\partial \pi_2}{\partial s} + m_{13} \frac{\partial \pi_3}{\partial s} \right) + \sum_{i=1}^{3} A_{2i} \left(m_{21} \frac{\partial \pi_1}{\partial s} + m_{22} \frac{\partial \pi_2}{\partial s} + m_{23} \frac{\partial \pi_3}{\partial s} \right) + \sum_{i=1}^{3} A_{3i} \left(m_{31} \frac{\partial \pi_1}{\partial s} + m_{32} \frac{\partial \pi_2}{\partial s} + m_{33} \frac{\partial \pi_3}{\partial s} \right) = 1$$

Assume $m_{11} = m_{22} = m_{33} = m$ – i.e., a constant value of own life.

(12)

$$m \left[\sum_{i=1}^{3} A_{1i} \left(\frac{\partial \pi_1}{\partial s} + \frac{m_{12}}{m} \frac{\partial \pi_2}{\partial s} + \frac{m_{13}}{m} \frac{\partial \pi_3}{\partial s} \right) + \sum_{i=1}^{3} A_{2i} \left(\frac{m_{21}}{m} \frac{\partial \pi_1}{\partial s} + \frac{\partial \pi_2}{\partial s} + \frac{m_{23}}{m} \frac{\partial \pi_3}{\partial s} \right) + \sum_{i=1}^{3} A_{3i} \left(\frac{m_{31}}{m} \frac{\partial \pi_1}{\partial s} + \frac{m_{32}}{m} \frac{\partial \pi_2}{\partial s} + \frac{\partial \pi_3}{\partial s} \right) \right] = 1$$

Multiply both sides by $\frac{\partial s}{\sum_{i=1}^{2} \partial \pi_i}$, which is the marginal cost of saving one additional life.

(13) $$\frac{\partial s}{\sum_{i=1}^{3} \partial \pi_i} m \left[\sum_{i=1}^{3} A_{1i} \left(\frac{\partial \pi_1}{\partial s} + \frac{m_{12}}{m} \frac{\partial \pi_2}{\partial s} + \frac{m_{13}}{m} \frac{\partial \pi_3}{\partial s} \right) + \sum_{i=1}^{3} A_{2i} \left(\frac{m_{21}}{m} \frac{\partial \pi_1}{\partial s} + \frac{\partial \pi_2}{\partial s} + \frac{m_{23}}{m} \frac{\partial \pi_3}{\partial s} \right) + \sum_{i=1}^{3} A_{3i} \left(\frac{m_{31}}{m} \frac{\partial \pi_1}{\partial s} + \frac{m_{32}}{m} \frac{\partial \pi_2}{\partial s} + \frac{\partial \pi_3}{\partial s} \right) \right] = \frac{\partial s}{\sum_{i=1}^{3} \partial \pi_i}$$

(14) $$m \left[\sum_{i=1}^{3} A_{1i} \left(\frac{\frac{\partial \pi_1}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} + \frac{m_{12}}{m} \frac{\frac{\partial \pi_2}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} + \frac{m_{13}}{m} \frac{\frac{\partial \pi_3}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} \right) + \sum_{i=1}^{3} A_{2i} \left(\frac{m_{21}}{m} \frac{\frac{\partial \pi_1}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} + \frac{\frac{\partial \pi_2}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} + \frac{m_{23}}{m} \frac{\frac{\partial \pi_3}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} \right) + \sum_{i=1}^{3} A_{3i} \left(\frac{m_{31}}{m} \frac{\frac{\partial \pi_1}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} + \frac{m_{32}}{m} \frac{\frac{\partial \pi_2}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} + \frac{\frac{\partial \pi_3}{\partial s}}{\frac{\sum_{i=1}^{3} \partial \pi_i}{\partial s}} \right) \right] = \frac{\partial s}{\sum_{i=1}^{3} \partial \pi_i}$$

Now, let $\sum_{i=1}^{2} \partial\pi_i = 1$. That is, one life is saved by the safety invention.

(15)

$$m\left[\sum_{i=1}^{3} A_{1i}\left(\frac{\frac{\partial\pi_1}{\partial s}}{\frac{1}{\partial s}} + \frac{m_{12}}{m}\frac{\frac{\partial\pi_2}{\partial s}}{\frac{1}{\partial s}} + \frac{m_{13}}{m}\frac{\frac{\partial\pi_3}{\partial s}}{\frac{1}{\partial s}}\right) + \sum_{i=1}^{3} A_{2i}\left(\frac{m_{21}}{m}\frac{\frac{\partial\pi_1}{\partial s}}{\frac{1}{\partial s}} + \frac{\frac{\partial\pi_2}{\partial s}}{\frac{1}{\partial s}} + \frac{m_{23}}{m}\frac{\frac{\partial\pi_3}{\partial s}}{\frac{1}{\partial s}}\right) + \sum_{i=1}^{3} A_{3i}\left(\frac{m_{31}}{m}\frac{\frac{\partial\pi_1}{\partial s}}{\frac{1}{\partial s}} + \frac{m_{32}}{m}\frac{\frac{\partial\pi_2}{\partial s}}{\frac{1}{\partial s}} + \frac{\frac{\partial\pi_3}{\partial s}}{\frac{1}{\partial s}}\right)\right] = \frac{\partial s}{\sum_{i=1}^{3}\partial\pi_i}$$

(16) $$m\left[\sum_{i=1}^{3} A_{1i}\left(\partial\pi_1 + \frac{m_{12}}{m}\partial\pi_2 + \frac{m_{13}}{m}\partial\pi_3\right) + \sum_{i=1}^{3} A_{2i}\left(\frac{m_{21}}{m}\partial\pi_1 + \partial\pi_2 + \frac{m_{23}}{m}\partial\pi_3\right) + \sum_{i=1}^{3} A_{3i}\left(\frac{m_{31}}{m}\partial\pi_1 + \frac{m_{32}}{m}\partial\pi_2 + \partial\pi_3\right)\right] = \frac{\partial s}{\sum_{i=1}^{3}\partial\pi_i}$$

Thus, the VSL multiplier is the term in brackets [].

Now express the VSL multiplier in matrix notation.

(17) $$\left[\sum_{i=1}^{3} A_{1i} \quad \sum_{i=1}^{3} A_{2i} \quad \sum_{i=1}^{3} A_{3i}\right] \times \begin{bmatrix} \partial\pi_1 + \frac{m_{12}}{m}\partial\pi_2 + \frac{m_{13}}{m}\partial\pi_3 \\ \frac{m_{21}}{m}\partial\pi_1 + \partial\pi_2 + \frac{m_{23}}{m}\partial\pi_3 \\ \frac{m_{31}}{m}\partial\pi_1 + \frac{m_{32}}{m}\partial\pi_2 + \partial\pi_3 \end{bmatrix}$$

(18) $$\left[\begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix}\begin{bmatrix}1\\1\\1\end{bmatrix}\right]' \times \begin{bmatrix} \partial\pi_1 + \frac{m_{12}}{m}\partial\pi_2 + \frac{m_{13}}{m}\partial\pi_3 \\ \frac{m_{21}}{m}\partial\pi_1 + \partial\pi_2 + \frac{m_{23}}{m}\partial\pi_3 \\ \frac{m_{31}}{m}\partial\pi_1 + \frac{m_{32}}{m}\partial\pi_2 + \partial\pi_3 \end{bmatrix}$$

(19) $$\left[\begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix}\begin{bmatrix}1\\1\\1\end{bmatrix}\right]' \times \left[\begin{bmatrix} 1 & \frac{m_{12}}{m} & \frac{m_{13}}{m} \\ \frac{m_{21}}{m} & 1 & \frac{m_{23}}{m} \\ \frac{m_{31}}{m} & \frac{m_{32}}{m} & 1 \end{bmatrix}\begin{bmatrix}\partial\pi_1\\ \partial\pi_2\\ \partial\pi_3\end{bmatrix}\right]$$

(20) $$\left[\begin{bmatrix} 1 & n_{21} & n_{31} \\ n_{12} & 1 & n_{32} \\ n_{13} & n_{23} & 1 \end{bmatrix}^{-1}\begin{bmatrix}1\\1\\1\end{bmatrix}\right]' \times \left[\begin{bmatrix} 1 & \frac{m_{12}}{m} & \frac{m_{13}}{m} \\ \frac{m_{21}}{m} & 1 & \frac{m_{23}}{m} \\ \frac{m_{31}}{m} & \frac{m_{32}}{m} & 1 \end{bmatrix}\begin{bmatrix}\partial\pi_1\\ \partial\pi_2\\ \partial\pi_3\end{bmatrix}\right]$$

Extending this problem to an n-person world yields the VSL multiplier given in the main text in Equation (2): $\left[\left(N'^{-1} \times W\right) \times (M \times D)\right]$.

Appendix B: Survey Questions

The following pages show the information and questions that were presented to Knowledge Networks' survey respondents. Each page corresponds to the information that was displayed on a single computer screen.

Question 1: What is your age? Click on the box next to your age.

- Age 18-29 ☐
- Age 30-39 ☐
- Age 40-49 ☐
- Age 50-59 ☐
- Age 60-69 ☐
- Age 70-79 ☐
- Age 80 or older ☐

Question 2: How many living immediate family members do you have in each age group? If you do not know the age of the family member, please give your best guess. If you do not have any immediate family members who are in this age group, please leave the cell blank. The sum of your entries should match the total number of living immediate family members you have of each type.

	Enter the *number* of family members of each type in each cell										
Type of immediate family member	**Age 0-4**	**Age 5-9**	**Age 10-17**	**Age 18-29**	**Age 30-39**	**Age 40-49**	**Age 50-59**	**Age 60-69**	**Age 70-79**	**Age 80 or older**	**Sum of your entries**
Your parents (including mother, father, stepmother, stepfather)											
Your siblings (including brothers, sisters, step-siblings, half-siblings)											
Your spouse or partner (including long-term relationships)											
Your children (including biological and adopted children)											

Question 3: How many living extended family members do you have in total by type?
Enter the TOTAL NUMBER of living extended family members you have of each type. If you do not know the exact number, please give your best guess. If you do not have any family members living in this category (for example, if your grandparents are not living or you have never had children), then enter "0".

Type of extended family member	**Enter the *TOTAL NUMBER* of each type in each cell**
Your grandparents (your parents' / stepparents' biological parents)	☐
Your aunts and uncles (your parents' / stepparents' siblings and their spouses)	☐
Your cousins (children of your aunts and uncles)	☐
Your siblings' spouse(s) (your sisters-in-laws & brothers-in-law via your siblings)	☐
Your siblings' children (your nieces and nephews)	☐
Your spouse or partner's parents (your mother-in-law, father-in-law)	☐
Your spouse or partner's siblings (your sisters-in-law & brothers-in-law via your spouse)	☐
Your children's spouses (your daughters-in-law, sons-in-law)	☐
Your grandchildren (your children's children)	☐

Question 4: Do you have ANY living extended family members in each age group? Click on the box if you have ANY living extended family members in this age group. Please give your best guess if you are not sure of extended family members' ages.

	Age 0-4	Age 5-9	Age 10-17	Age 18-29	Age 30-39	Age 40-49	Age 50-59	Age 60-69	Age 70-79	Age 80 or older	***TOTAL NUMBER*** **of extended family members from question 3.**
	Click on the box if you believe the you have *ANY* living extended family members in this cell.										
Extended family include your:											

Grandparents,
Aunts and Uncles,
Cousins,
Siblings' Spouse(s),
Siblings' Children (Nephews and Nieces),
Spouse's Parents,
Spouse's Siblings,
Children's Spouse(s), and
Grandchildren

Question 5: How many close friends, co-workers, and acquaintances do you have? Enter the TOTAL NUMBER of your close friends, co-workers, and acquaintances. We understand that you are unlikely to know the exact number -- please give your best guess. If you do not have any persons in this category (for example, you have no co-workers as you are unemployed), then enter "0".

Type of relation	Enter the ***TOTAL NUMBER*** of each type in each cell
Close Friends (Include non-family members who you have close friendship with. For example, someone you talk with regularly and have a strong friendly bond).	☐
Co-workers (Include anyone you work with regularly who is not a family member or close friend.)	☐
Acquaintances (Include anyone who is not a family member, close friend, or co-worker who you know well enough that you would say "hello" to if you passed them on the street.)	☐

Question 6: What are the ages of your close friends, co-workers, and acquaintences? Click on the boxes that best reflect the ages of your close friends, co-workers, and acquaintences. For example, if most of your close friends are aged 30-39 or 40-49, then you would click on both of these boxes in the "Close Friends" row. If your co-workers are equally spread between the ages 18 and 65, you would click all of the boxes in the "Co-workers" row except Aged 0-4, 5-9, 10-17, 70-79, and 80 or older.

Type of relation	Age 0-4	Age 5-9	Age 10-17	Age 18-29	Age 30-39	Age 40-49	Age 50-59	Age 60-69	Age 70-79	Age 80 or older	***TOTAL NUMBER*** **of this type from question 5.**
Close Friends (Include non-family members who you have close friendship with. For example, someone you talk with regularly and have a strong friendly bond).											
Co-workers (Include anyone you work with regularly who is not a family member or close friend.)											
Acquaintances (Include anyone who is not a family member, close friend, or co-worker who you know well enough that you would say "hello" to if you passed them on the street.)											

(The age columns are headed: **Click on the boxes that best reflect the ages of this type of relation**)

Preview to Questions 7 and 8

The next two sets of questions will ask you to make choices about things where chance or luck plays a role in the outcome.

An example of a chance event is the flipping of a coin. If a coin were tossed 100 times, on average it would land on heads 50 times and land on tails 50 times.

Likewise, if a coin were tossed 1,000 times, on average it would land on heads 500 times and land on tails 500 times.

Preview to Questions 7 and 8 (Continued)

Another example is a roulette wheel.

An American roulette wheel has 38 slots.

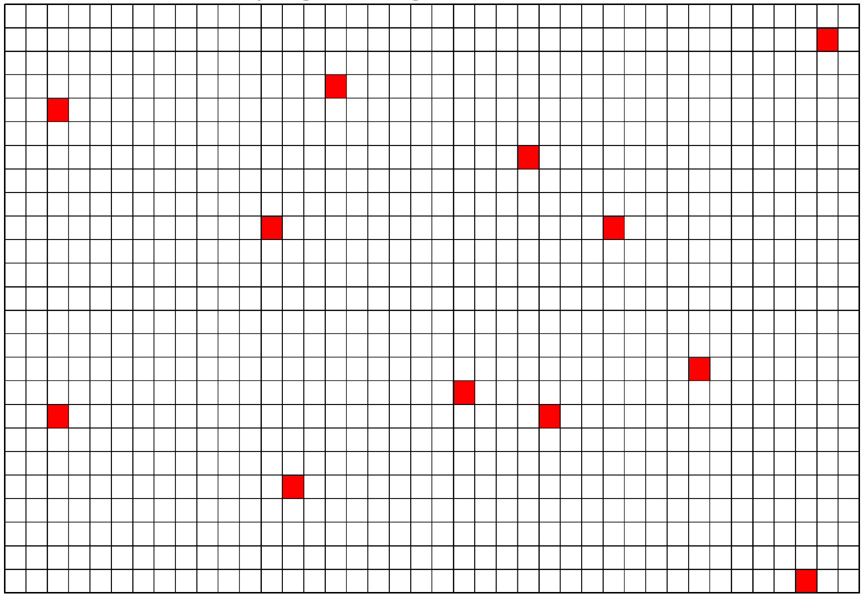
The ball should land in any given spot (for example the #7 slot), once out of every 38 spins.

If the roulette wheel were spun 38,000 times, on average the ball will land in the #7 slot 1,000 times.

Preview to Question 7: Chance of Dying During the Next 10 Years

Question 7 will include an estimate of the chance of you or others dying during the next 10 years. For example, for a typical 25 year old living in the United States, the chance of dying before age 35 is 12 out of 1,000:

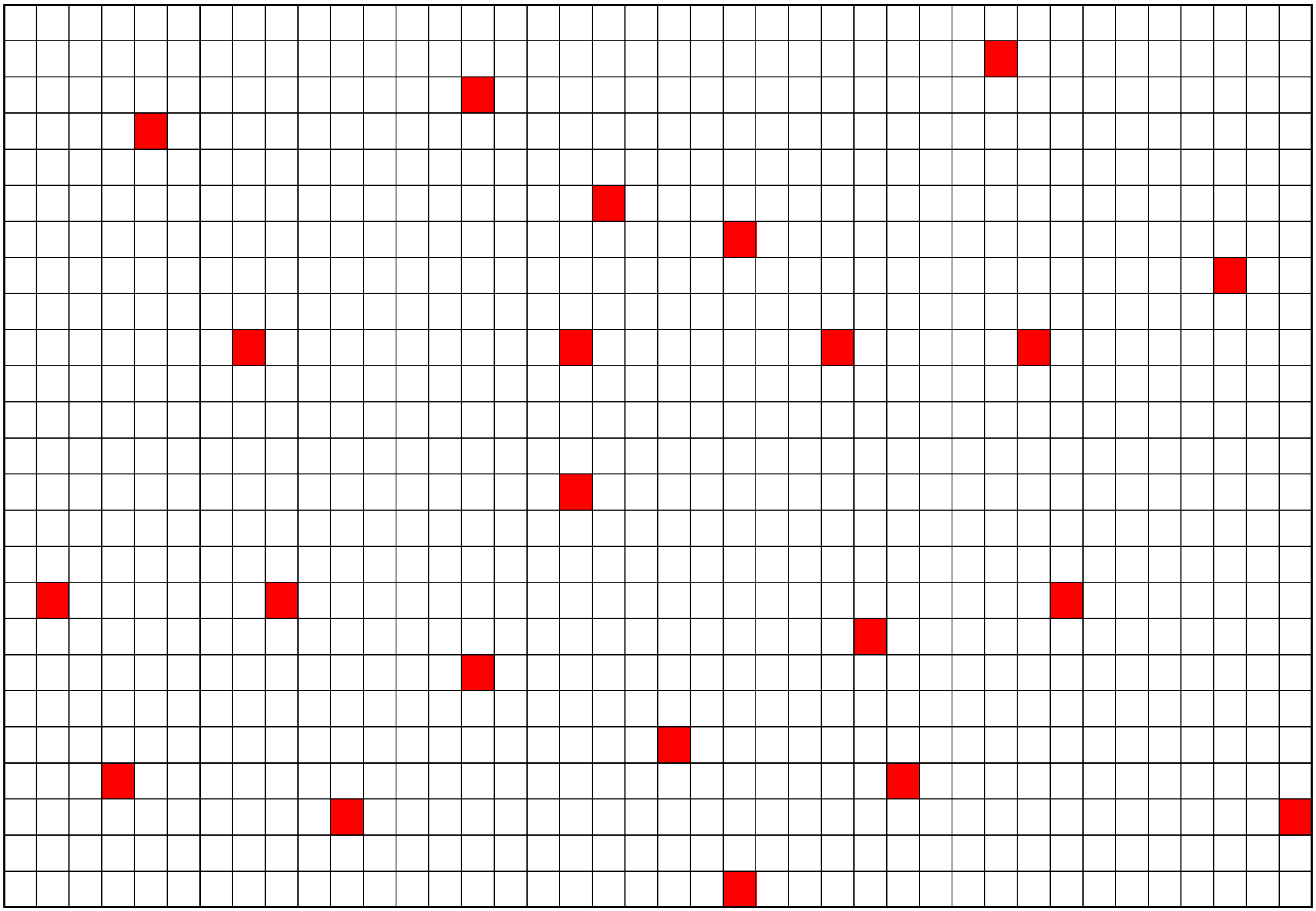
Age **25**: Chance of Dying During Next 10 Years = **12** out of 1,000.



There are 1,000 squares shown. The number of red squares is equal to the number of chances out of 1,000 that the typical person will die within 10 years. You can think of each square like the slot on a roulette wheel, where if by chance the roulette ball landed in a red square, the person would unfortunately die. As shown on the next several pages, as people age, the chance of dying during the next 10 years rises.

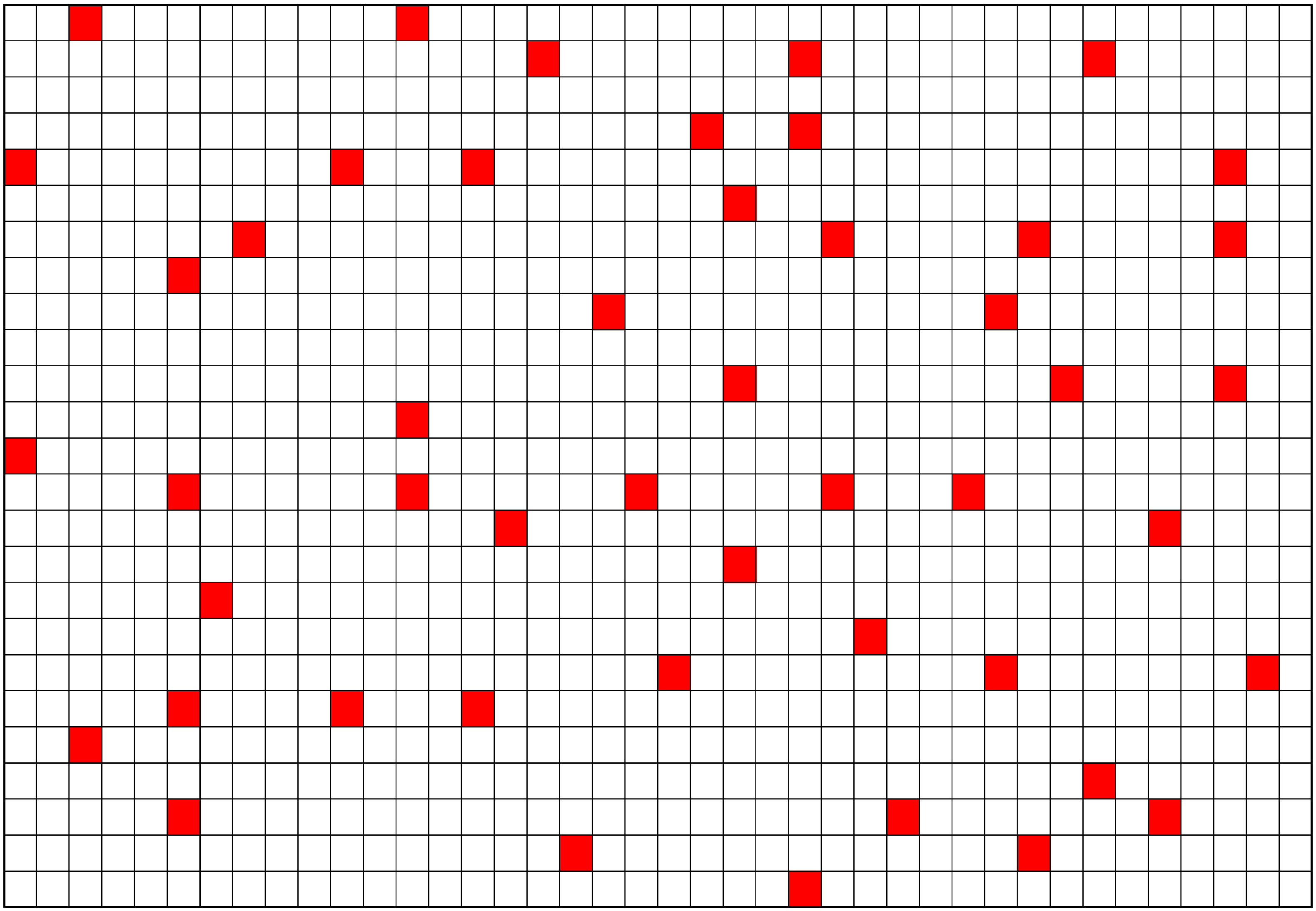
Preview to Question 7 (continued)

Age **35**: Chance of Dying During Next 10 Years = **22** out of 1,000.



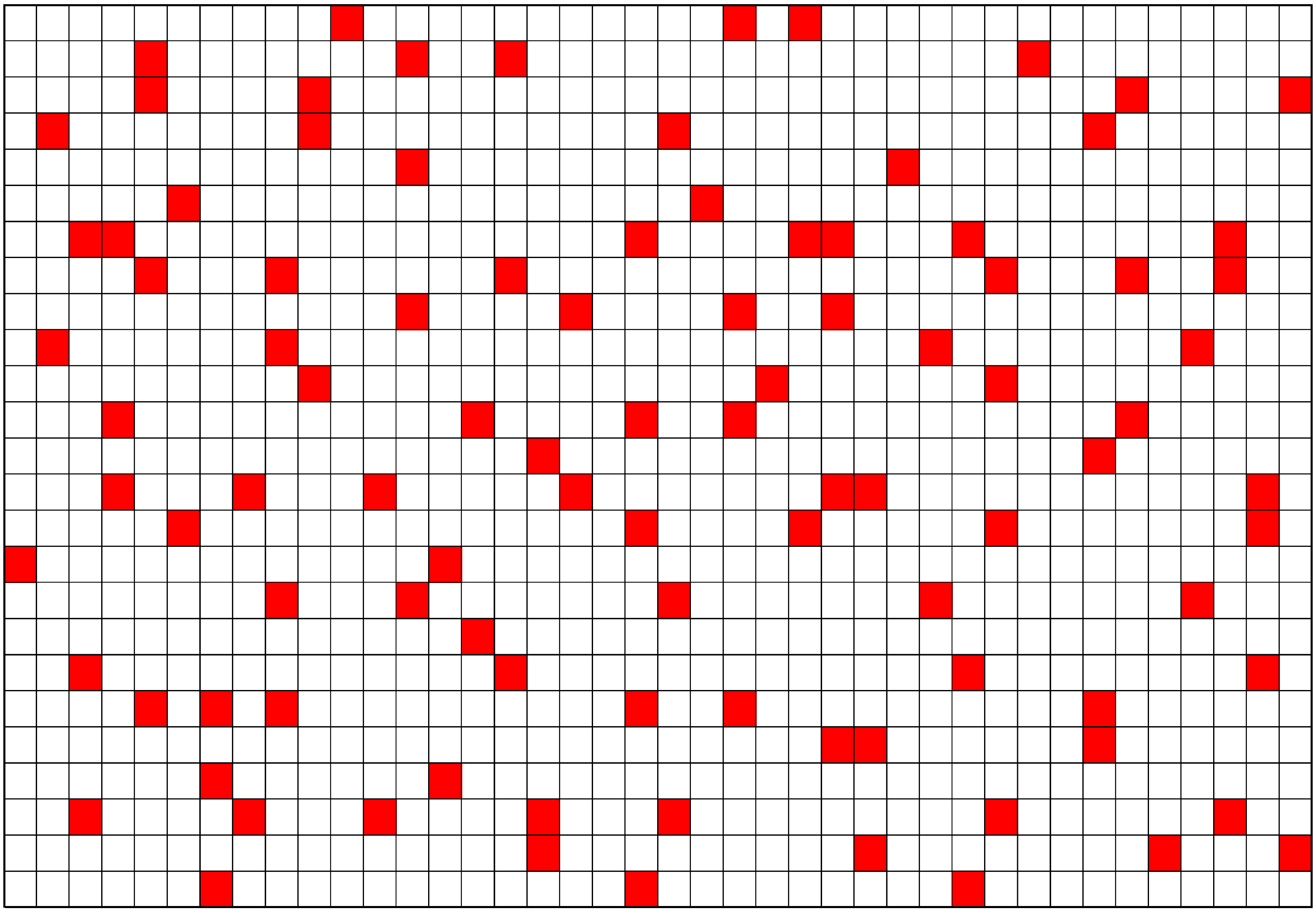
Preview to Question 7 (continued)

Age **45**: Chance of Dying During Next 10 Years = **48** out of 1,000.



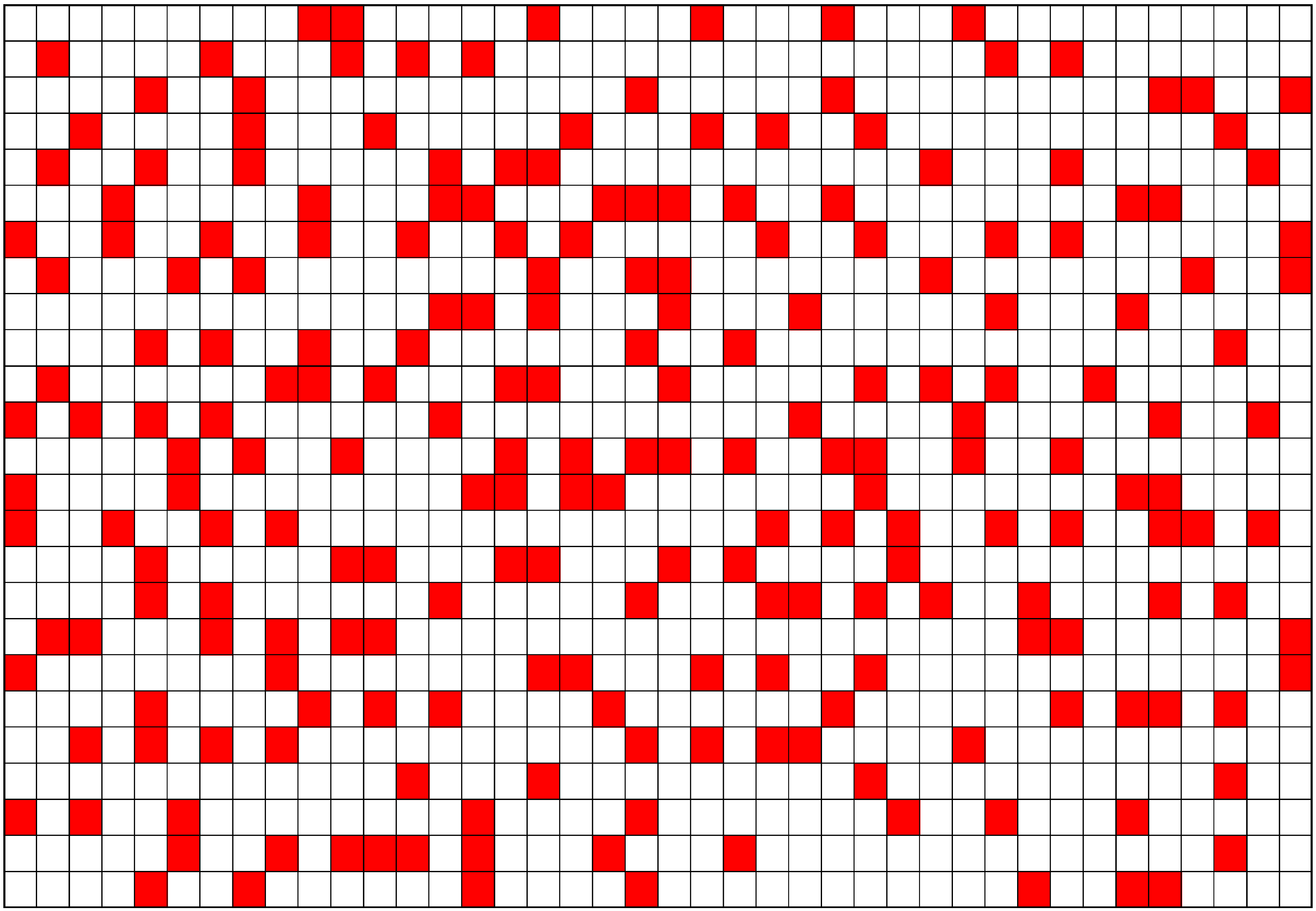
Preview to Question 7 (continued)

Age **55**: Chance of Dying During Next 10 Years = **101** out of 1,000.



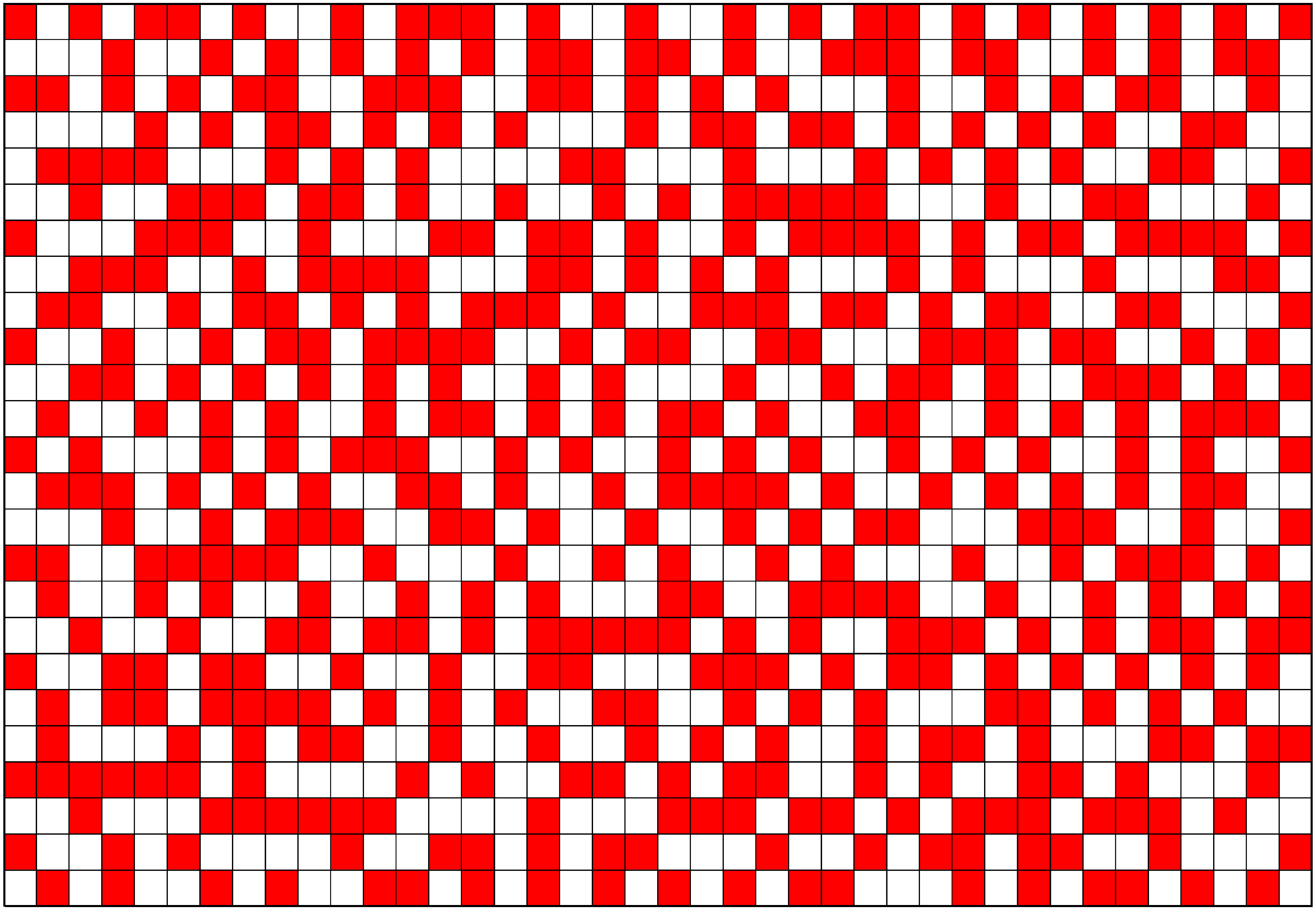
Preview to Question 7 (continued)

Age **65**: Chance of Dying During Next 10 Years = **219** out of 1,000.



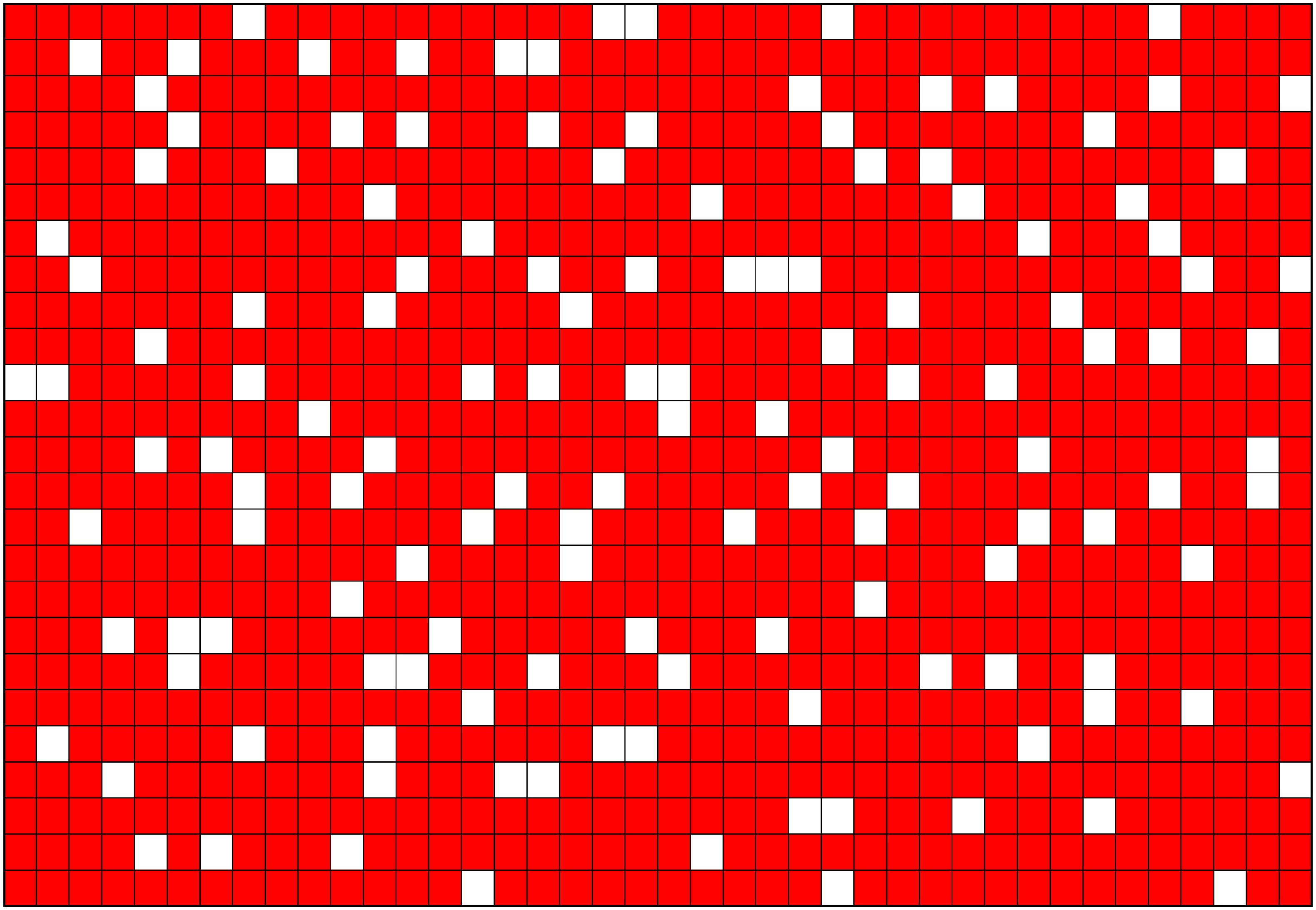
Preview to Question 7 (continued)

Age **75**: Chance of Dying During Next 10 Years = **490** out of 1,000.



Preview to Question 7 (continued)

Age **85**: Chance of Dying During Next 10 Years = **863** out of 1,000.

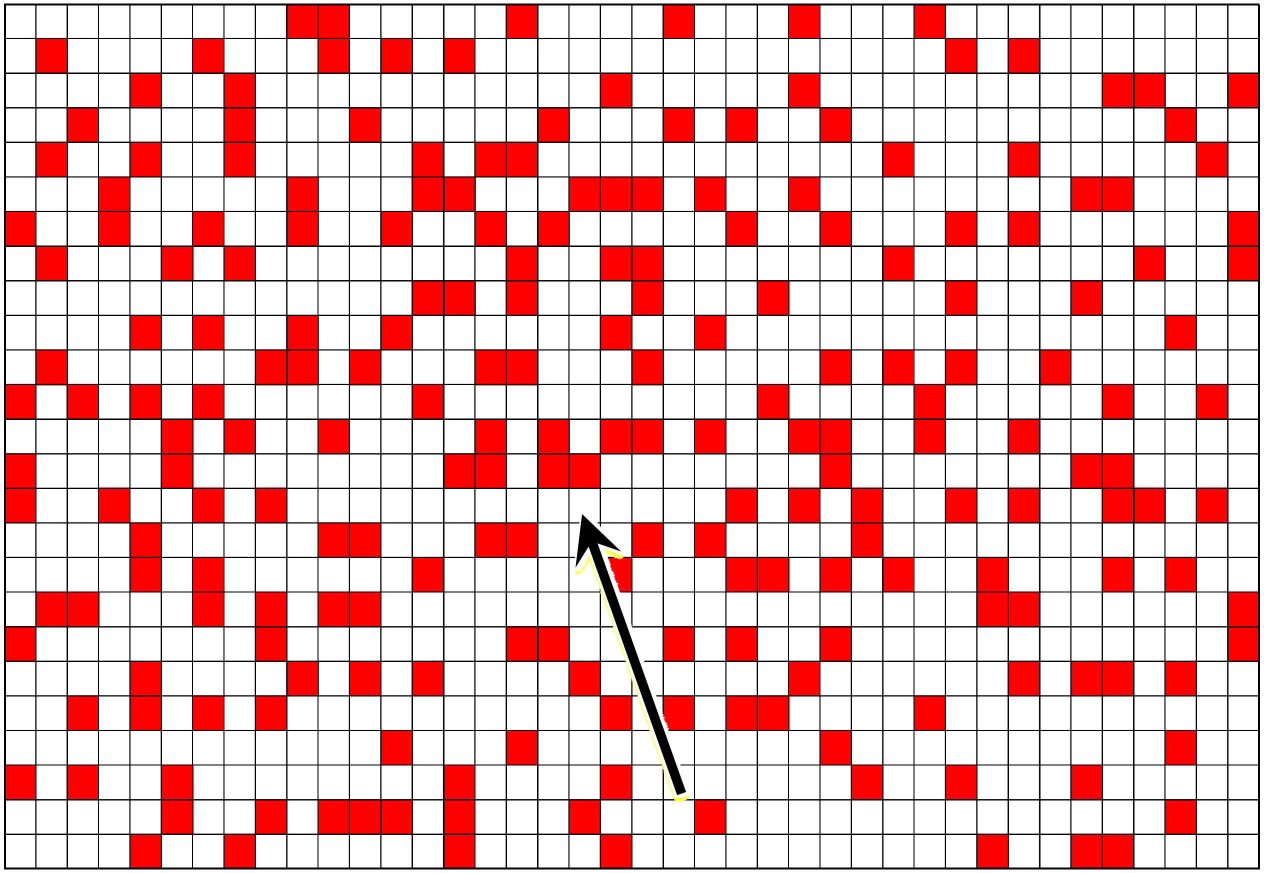


Preview to Question 7 (continued)

Take the case of a 65 year old. Out of one thousand 65 year olds, 219 die before they reach 75 years old. Imagine a roulette ball randomly landing in one of the squares on the grid. If the ball lands in a white square, the person lives to age 75.

Age **65**: Chance of Dying During Next 10 Years = **219** out of 1,000.

(Result: Lives to Age 75)

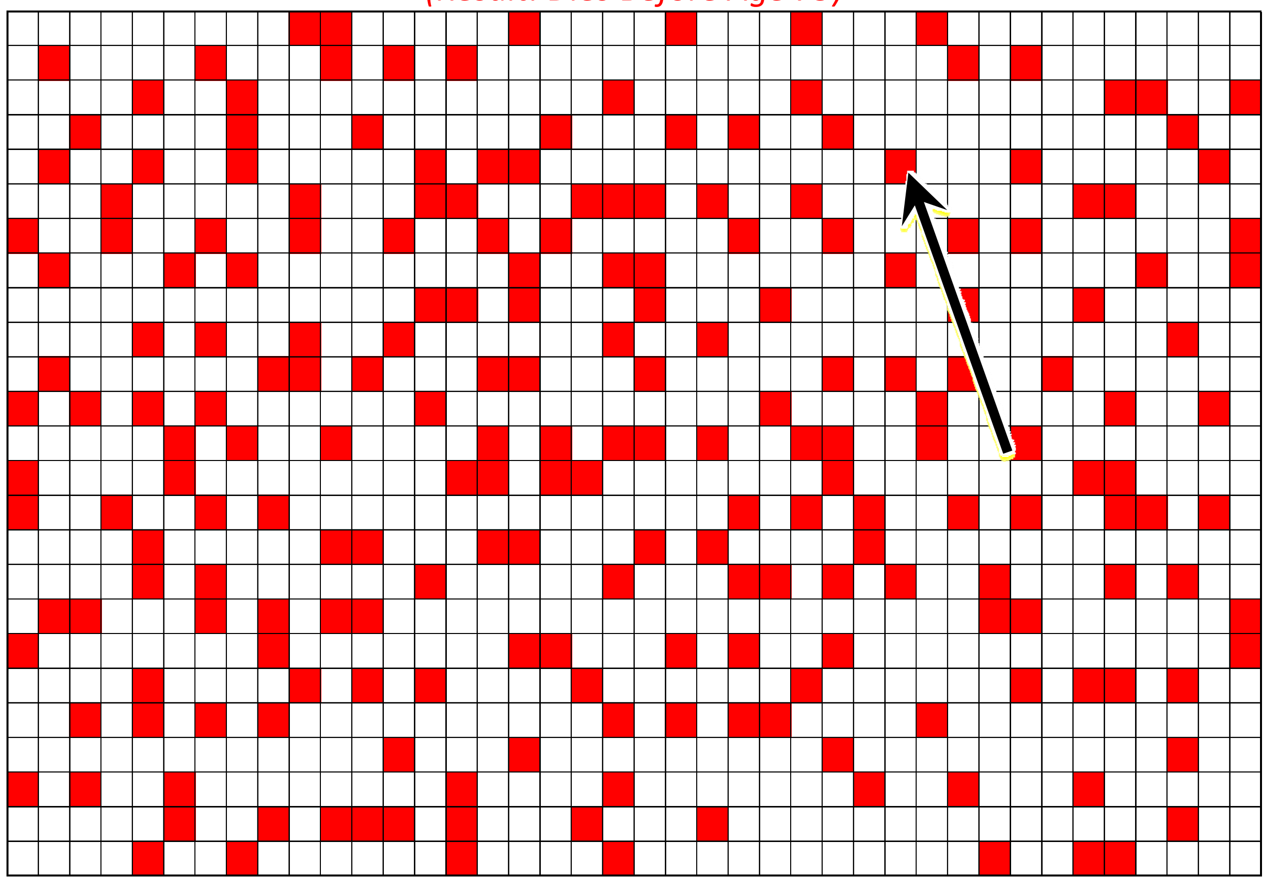


Preview to Question 7 (continued)

If the ball lands in a red square the person dies before age 75. Out of 1,000 spins of the roulette wheel, we would expect the ball to land in a red square 219 times.

Age **65**: Chance of Dying During Next 10 Years = **219** out of 1,000.

(Result: Dies Before Age 75)



Preview to Question 7 (continued): Medical Products & Safety Inventions

Now, imagine that a company decided to give out special medical products and/or safety inventions that could lower a person's chance of dying during the next 10 years. A medical "product" could include things like drugs, immunizations, and new medical screening technologies that can catch diseases and cancers while they are still treatable. Life-saving inventions include things like car safety devices that lower the risk of serious accidents or technologies that help prevent accidental drowning, poisoning, falling, electrocution, etc. Assume that these products and inventions have no side effects and that these products / inventions are not available on the market and can be obtained only by the company's donation to a person.

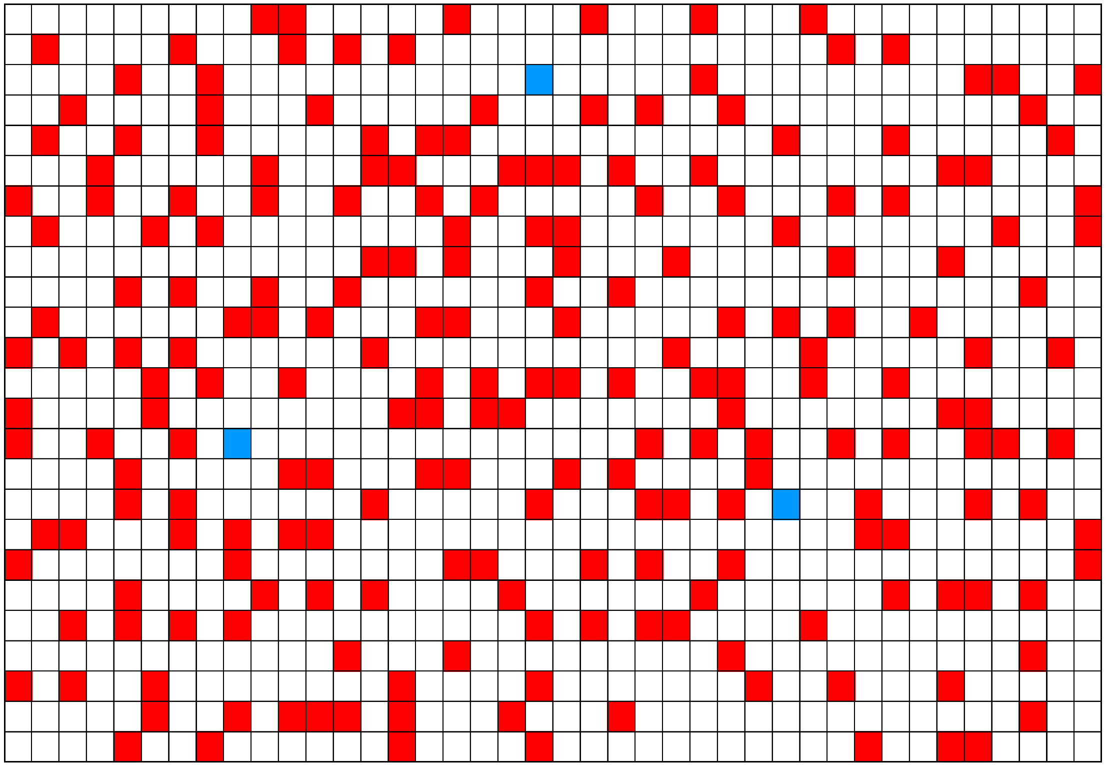
Assume that the company has decided to give out 10 of these medical products and/or safety inventions and they will be given to you and/or one other person. Once they are given out, assume that they cannot be given or sold to someone else.

Each product or invention given will lower the recipient's chance of dying during the next 10 years by one chance in 1,000. Thus, if the company gives 5 medical products or inventions to a person, the person's chance of dying during the next 10 years would decline by 5 chances in 1,000.

Preview to Question 7 (continued)

Imagine three medical products or safety inventions are given to a 65 year old. The three products or inventions would lower the person's chance of death before age 75 from 219 out of 1,000 to 216 out of 1,000. The change in the person's chance of death is shown in the following figure. The three blue squares were previously red squares, and reflect the reduction in the chance of death that is caused by the receipt of the three medical products or safety inventions.

Age **65**: Chance of Dying During Next 10 Years = ***216*** out of 1,000 after the donation by the company.

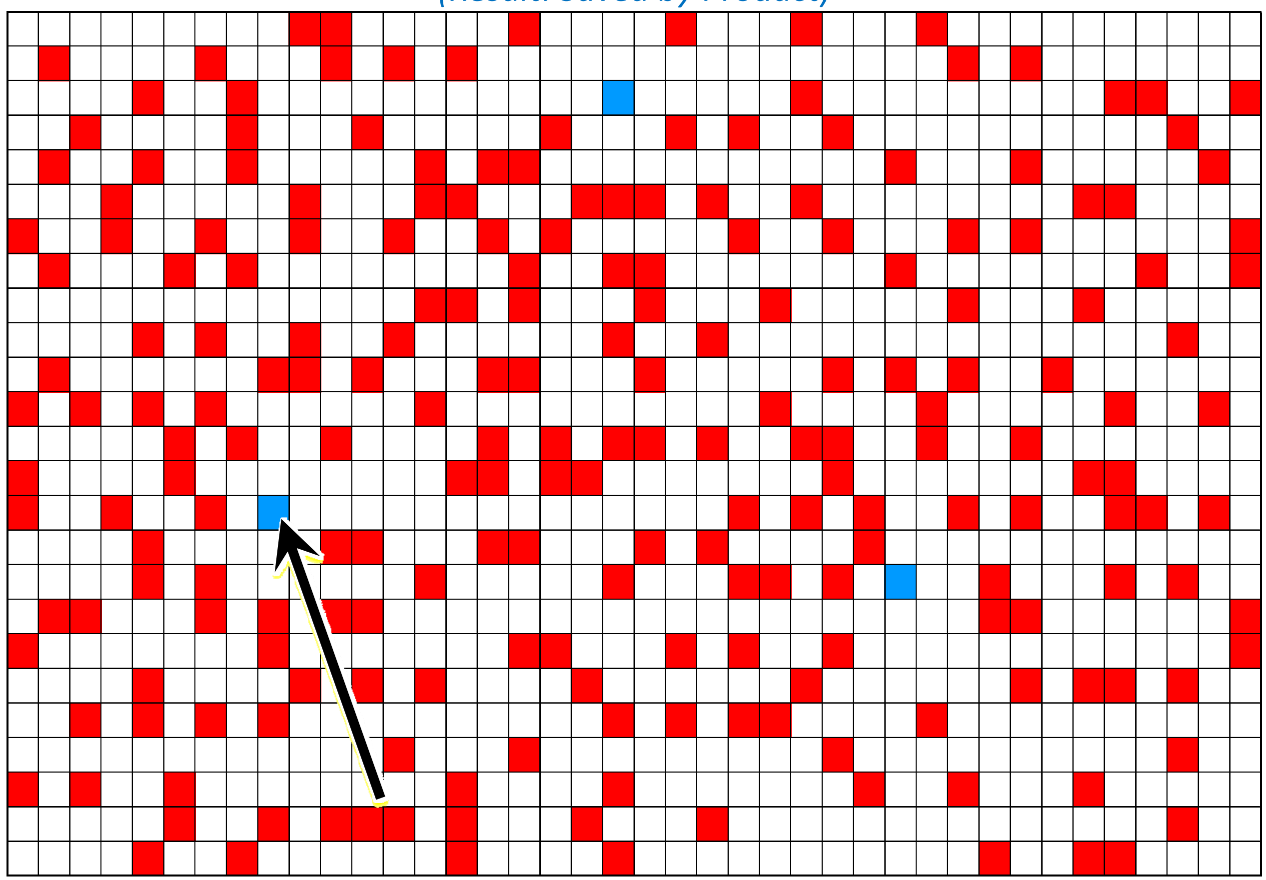


Preview to Question 7 (continued)

If the roulette ball happens to land in one of these three blue squares, then the person's life is extended by the new product or invention.

Age **65**: Chance of Dying During Next 10 Years = **216** out of 1,000.

(Result: Saved by Product)

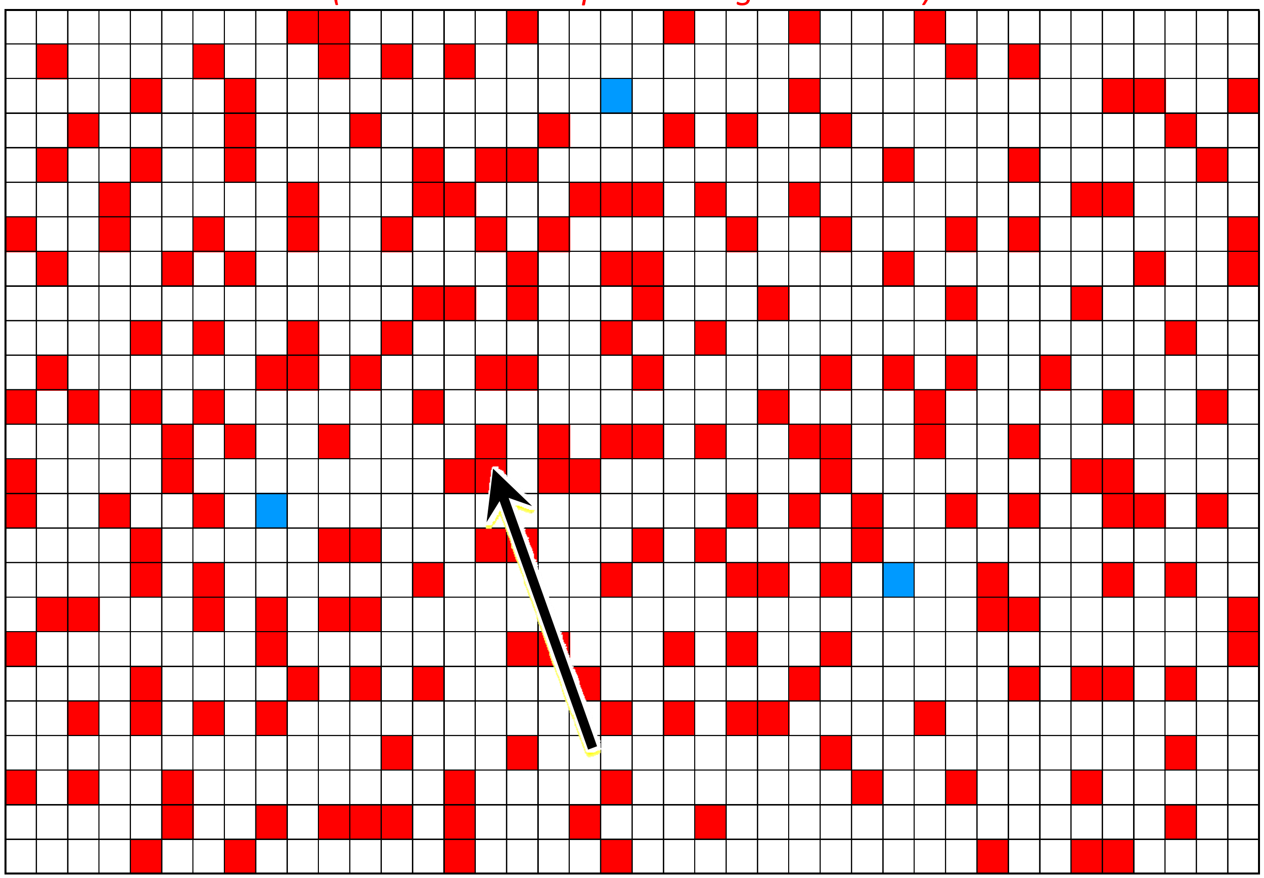


Preview to Question 7 (continued)

If the ball lands in a red square, the person dies before age 75, and this reflects a death that the new product or invention could not prevent.

Age **65**: Chance of Dying During Next 10 Years = **216** out of 1,000.

(Result: Dies Despite Having 3 Products)

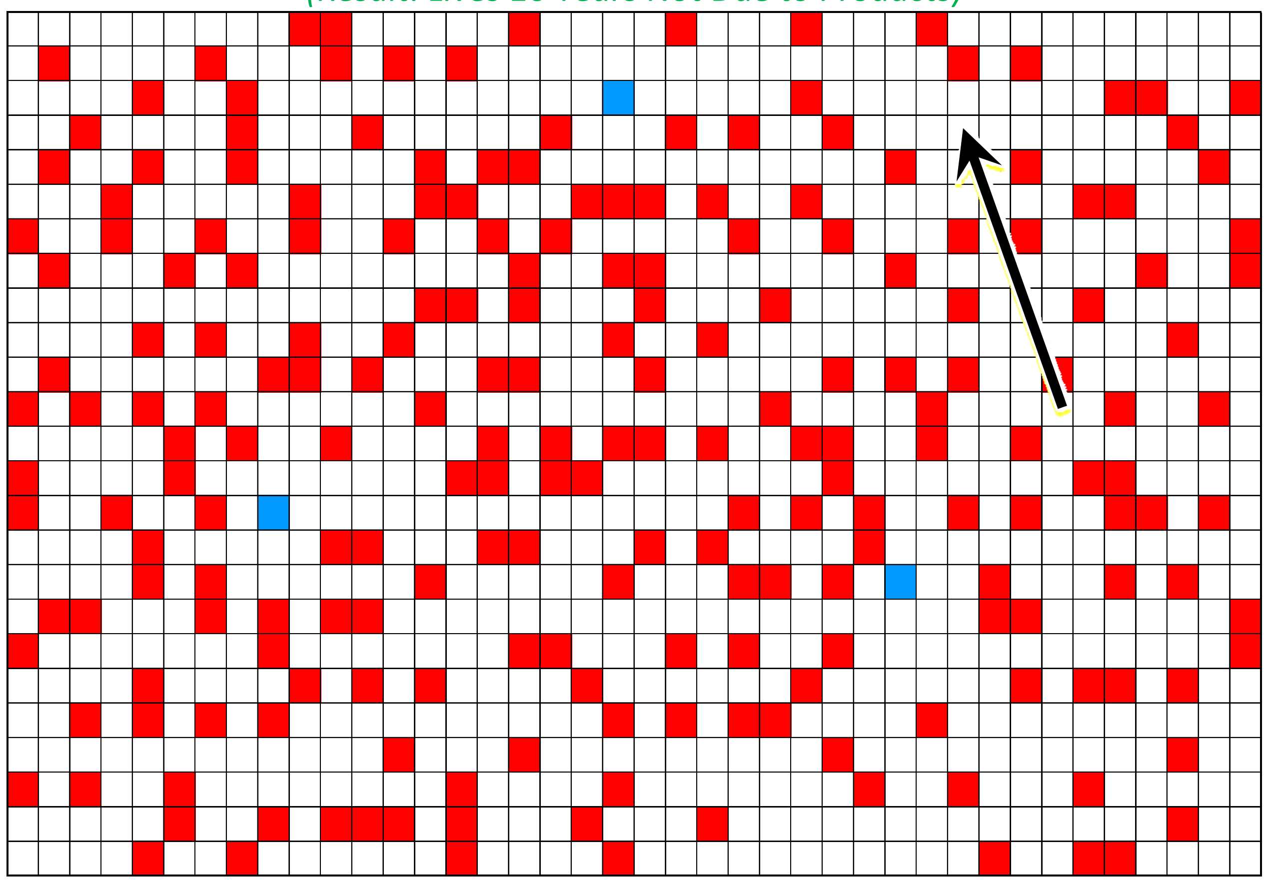


Preview to Question 7 (continued)

Finally, if the ball lands in a white square, the person lives to age 75, for reasons unrelated to having the new product/invention.

Age **65**: Chance of Dying During Next 10 Years = **216** out of 1,000.

(Result: Lives 10 Years Not Due to Products)



Preview to Question 7 (continued)

Suppose that the company has asked you to deal out the 10 medical products and safety inventions between yourself and one other person. You are allowed to deal out the products and inventions in any way you choose. You can select any of the following choices:

Number given to:	
You	**Other Person**
All 10	None
9	1
8	2
7	3
6	4
5	5
4	6
3	7
2	8
1	9
None	All 10

In Question 7, you will be told the age range of the other person (for example, age 60-69), and their relationship to you (for example, “an acquaintance”). You will be asked ten versions of Question 7 (labeled 7ȸм-7ȸмл), with each version varying the age of the other person and/or the relationship of the other person to you. In each question, you will be asked to select the number of medical products and safety inventions (between 0 and 10) that you would like to give to yourself, with the remainder going to the other person.

Preview to Question 7 (continued)

You will be shown the “baseline chance of dying within the next 10 years” for yourself and the other person. These figures are based on the mid-point of the age range. For example, when asked about someone aged 60-69, you will be shown his or her baseline chance of death during the next 10 years as 219 out of 1,000, which corresponds to the risk of death for a typical 65 year old. However, when asked about someone less than 20 years old, you will be shown their baseline chance of death during the next 10 years as 11 out of 1,000 (even though the typical youth has a slightly lower baseline chance of death).

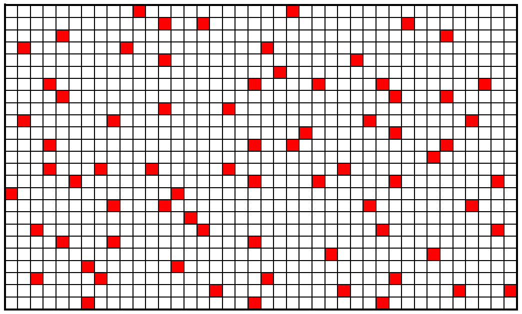
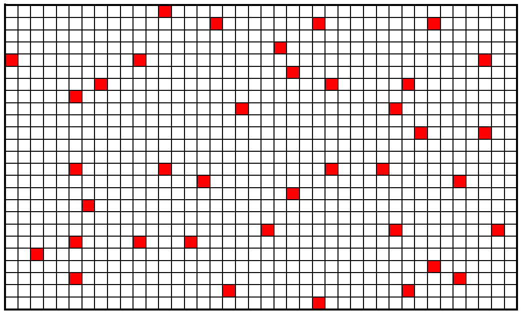
Likewise, the questions will list a chance of death during the next 10 years for you based on the mid-point of your age range. For example, if you are in your twenties, you will be shown the baseline chance of death during the next 10 years for a typical 25 year old. We would like to stress that this baseline risk of death is simply used for illustration purposes and may not correspond well with your actual risk of death in the next 10 years. A person’s risk of death is a function of the person’s age, gender, health status, and many other factors.

For each of these questions, you must enter a number between 0-10 in a blue box. The number you enter will be the number of medical products and safety inventions that go to you. After you do this, you will be shown the number of medical products and safety inventions that go to the other person, and will be shown how this donation of products and inventions has changed your chance of death during the next 10 years and how this donation has changed the other person’s chance of death during the next 10 years.

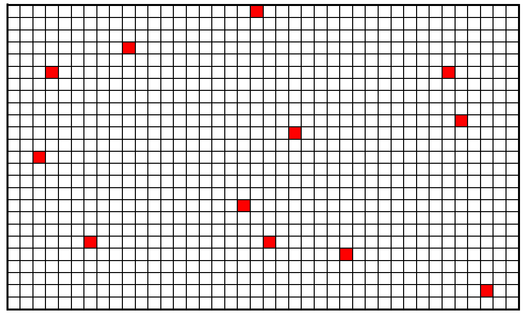
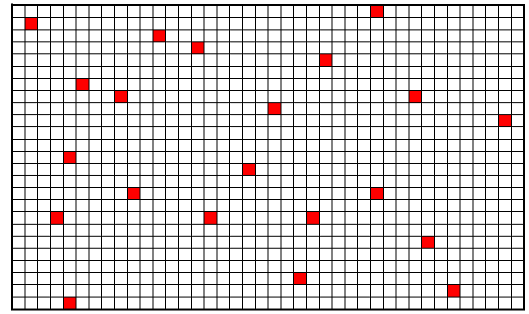
Assume that the other person will not know that you have been asked to make this choice to deal out the products. That is, your choice is unknown to the other person.

Before we get to Question 7, the next few questions are included to make sure you understand the concepts related to the chance of death within the next 10 years.

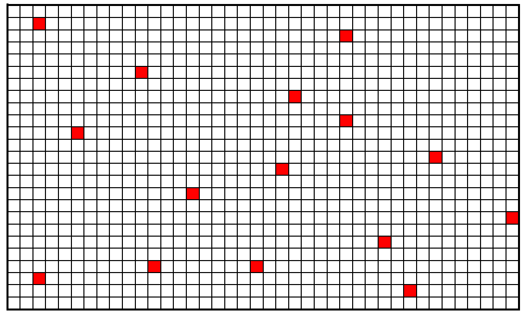
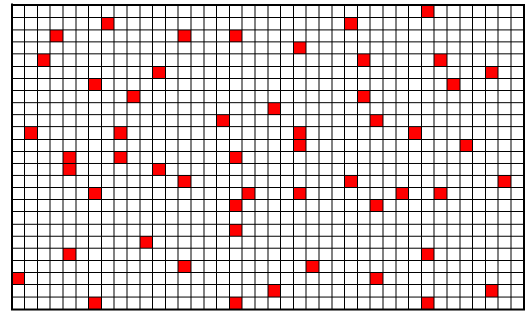
__Preview to Question 7__. **Warm-Up Question A: Which person who has the lower chance of dying in the next 10 years?** Click on the box of the person who has the lower chance of dying in the next 10 years.

	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Chance of dying within the next 10 years:	75 in 1,000 Chance		38 in 1,000 Chance
			
Add the following cell if they click on this person	**Not Correct. Person 1 has a *higher* chance of dying in the next 10 years than person 2.**		**Correct! Person 2 has a *lower* chance of dying in the next 10 years than person 1.**

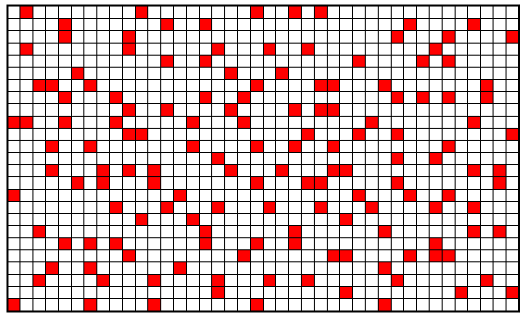
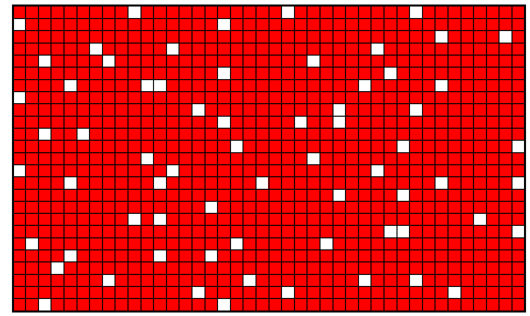
<u>Preview to Question 7</u>. Warm-Up Question A (Try Again): Which person who has the lower chance of dying in the next 10 years? Click on the box of the person who has the lower chance of dying in the next 10 years.

	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Chance of dying within the next 10 years:	12 in 1,000 Chance		21 in 1,000 Chance
			
Add the following cell if they click on this person	**Correct! Person 1 has a *lower* chance of dying in the next 10 years than person 2.**		**Not Correct. Person 2 has a *higher* chance of dying in the next 10 years than person 1.**

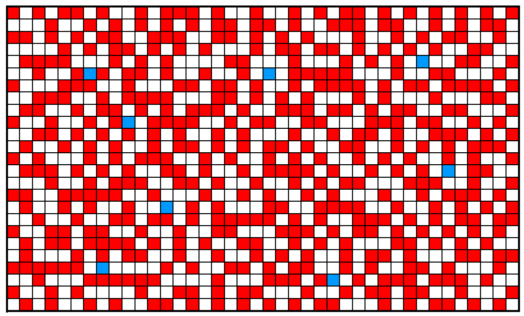
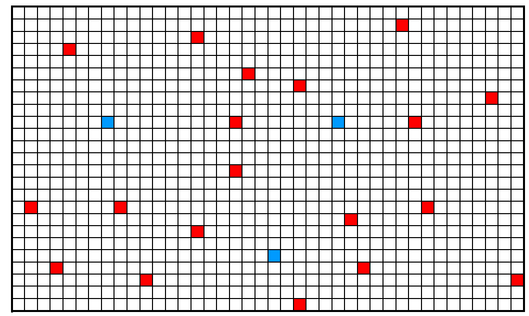
<u>Preview to Question 7</u>. Warm-Up Question B: Which person would you rather be (assuming that you want to live for 10 years)? Click on the box of the person you would rather be.

	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Chance of dying within the next 10 years:	15 in 1,000 Chance		53 in 1,000 Chance
			
Add the following cell if they click on this person	**Correct! Person 1 has a *lower* chance of dying in the next 10 years than person 2.**		**Not Correct. Person 2 has a *higher* chance of dying in the next 10 years than person 1.**

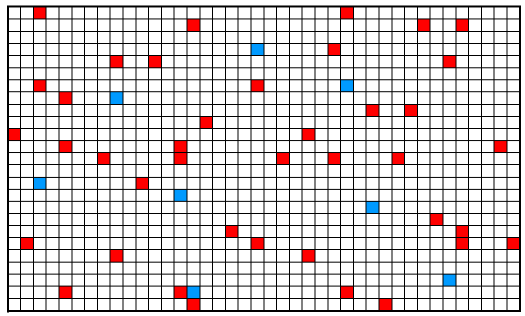
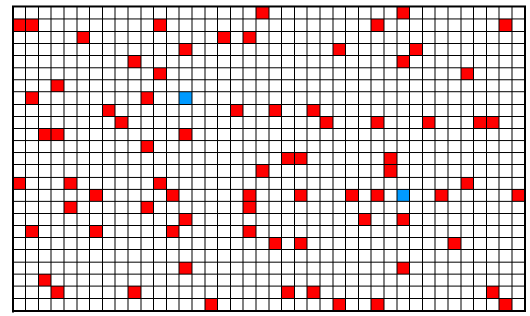
<u>Preview to Question 7</u>. Warm-Up Question B (Try Again): Which person would you rather be (assuming that you want to live for 10 years)?
Click on the box of the person you would rather be.

	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Chance of dying within the next 10 years:	153 in 1,000 Chance		934 in 1,000 Chance
			
Add the following cell if they click on this person	**Correct! Person 1 has a *lower* chance of dying in the next 10 years than person 2.**		**Not Correct. Person 2 has a *higher* chance of dying in the next 10 years than person 1.**

<u>Preview to Question 7</u>. Warm-Up Question C: Which person has the biggest reduction in the their chance of death during the next 10 years as a result of the company's donation of medical products or safety inventions? Click on the box of the person who has the biggest reduction in the their chance of death.

	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Company offers this number of medical products / safety inventions:	7		3
Baseline chance of dying within the next 10 years:	490 in 1,000 Chance		22 in 1,000 Chance
Chance of dying within the next 10 years ***AFTER*** medical products / safety inventions are given. (Red Squares):	483 in 1,000 Chance		19 in 1,000 Chance
			
Add the following cell if they click on this person	**Correct! The reduction in the number of chances of dying during the next 10 years is greater for person 1 than person 2.**		**Not Correct. The reduction in the number of chances of dying during the next 10 years is smaller for person 2 than person 1.**

<u>Preview to Question 7</u>. Warm-Up Question C (Try Again): Which person has the biggest reduction in the their chance of death during the next 10 years as a result of the company's donation of medical products or safety inventions? Click on the box of the person who has the biggest reduction in the their chance of death.

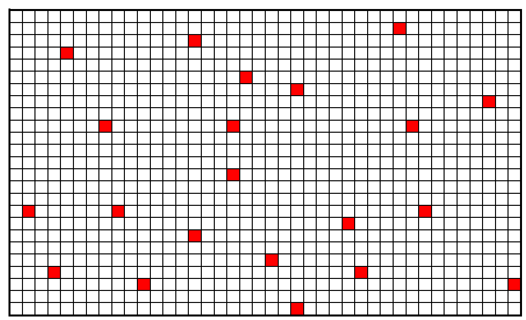
	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Company offers this number of medical products / safety inventions:	8		2
Baseline chance of dying within the next 10 years:	48 in 1,000 Chance		78 in 1,000 Chance
Chance of dying within the next 10 years ***AFTER*** medical products / safety inventions are given. (Red Squares):	40 in 1,000 Chance		76 in 1,000 Chance
			
Add the following cell if they click on this person	**Correct! The reduction in the number of chances of dying during the next 10 years is greater for person 1 than person 2.**		**Not Correct. The reduction in the number of chances of dying during the next 10 years is smaller for person 2 than person 1.**

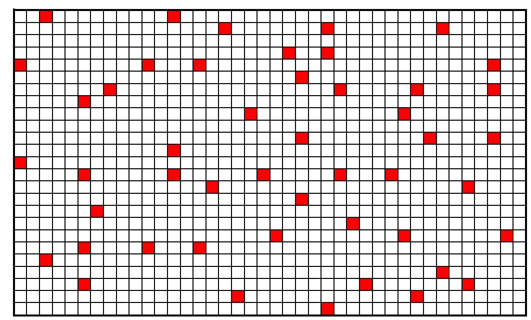
Question 7.1:

Out of the 10 medical products and safety inventions that the company gives out, how many would you like the company to give to you and how many would you like the company to give to the other person? Enter the number (between 0 and 10) in the blue box that you would like to be given to you. After you enter this number, the remainder (10 minus the number given to you) will be shown in the orange box, and the number of products/inventions given to you and the other person will be shown as blue squares in the grid below. You may change your entry in the blue box if you are not satisfied. Once you are satisfied with your choice, click the "Continue" button.

	You **age 30-39**	**Other person is** **an acquaintance** **age 40-49**
In the blue box, enter the number of medical products or safety inventions you would like to be given to you		
Baseline chance of dying within the next 10 years:	22 in 1,000 Chance	48 in 1,000 Chance

Continue

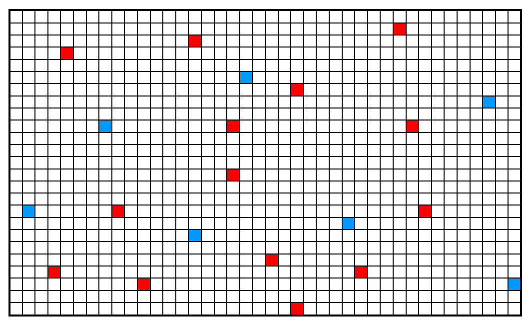


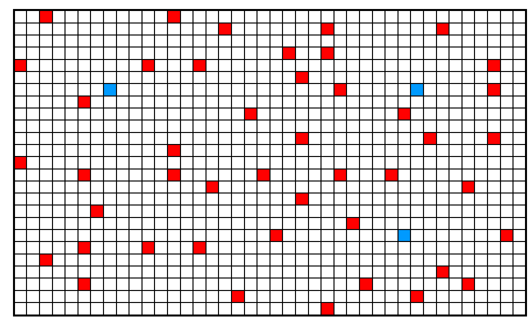


Question 7.1:

Out of the 10 medical products and safety inventions that the company gives out, how many would you like the company to give to you and how many would you like the company to give to the other person? Enter the number (between 0 and 10) in the blue box that you would like to be given to you. After you enter this number, the remainder (10 minus the number given to you) will be shown in the orange box, and the number of products/inventions given to you and the other person will be shown as blue squares in the grid below. You may change your entry in the blue box if you are not satisfied. Once you are satisfied with your choice, click the "Continue" button.

	You **age 30-39**	**Other person is** **an acquaintance** **age 40-49**
In the blue box, enter the number of medical products or safety inventions you would like to be given to you	**7**	**3**
	Continue	
Baseline chance of dying within the next 10 years:	22 in 1,000 Chance	48 in 1,000 Chance
Chance of dying within the next 10 years ***AFTER*** medical products / safety inventions are given. (Red Squares):	15 in 1,000 Chance	45 in 1,000 Chance



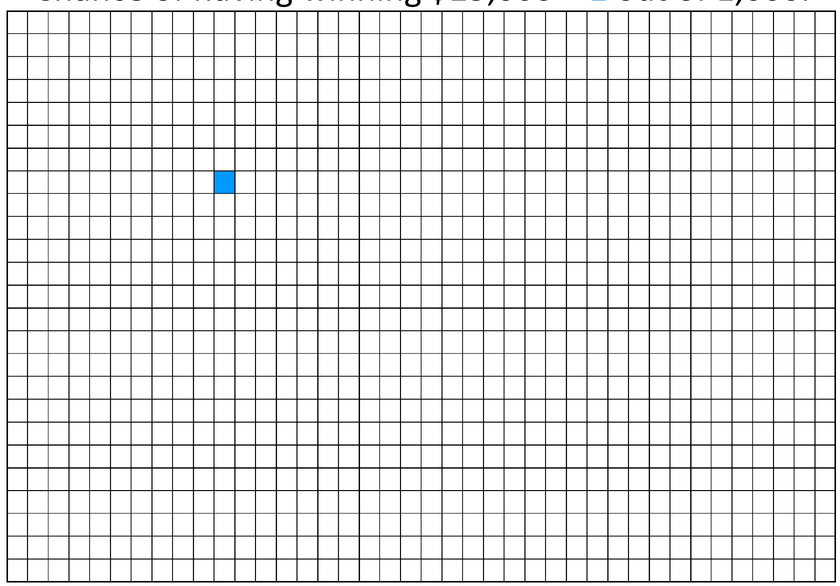


Preview to Question 8: Chance of Winning $25,000

Question 8 is about the chance of you or others winning money. Imagine that a company decided to give out ten scratch-off tickets and these ten tickets will be given to you and/or one other person. Once they are given out, assume that they cannot be given or sold to someone else. Each ticket has one chance in 1,000 of winning $25,000 from the company.

A person with one ticket has 1 chance in 1,000 to win $25,000. This relationship can be seen in this figure.

Chance of having winning $25,000 = **1** out of 1,000.



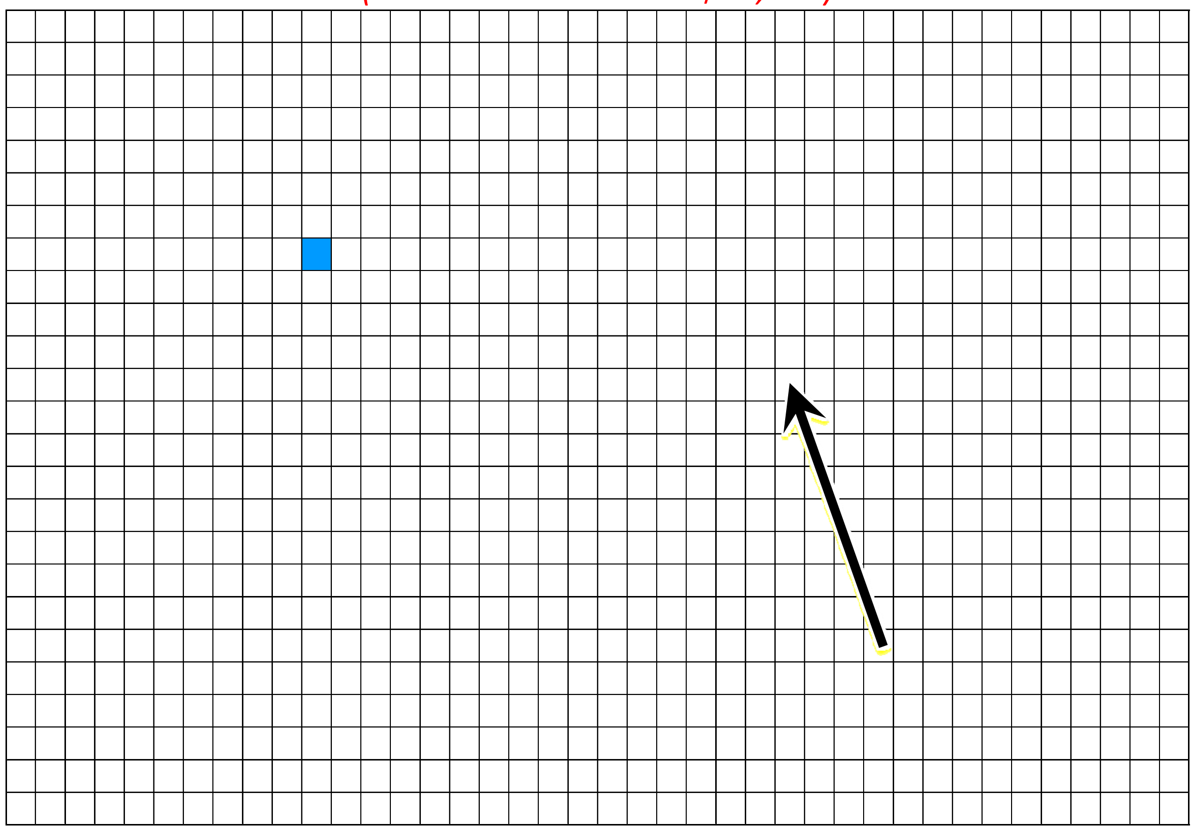
There are 1,000 squares shown. You can think of each square like the slot on a roulette wheel, where if by chance the roulette ball landed in a blue square, the person will win $25,000.

Preview to Question 8 (continued)

Imagine a roulette ball randomly landing in one of the squares on the grid. If the ball lands in a white square, the person will receive nothing.

Chance of Winning $25,000 = **1** out of 1,000.

(Result: Does Not Win $25,000)

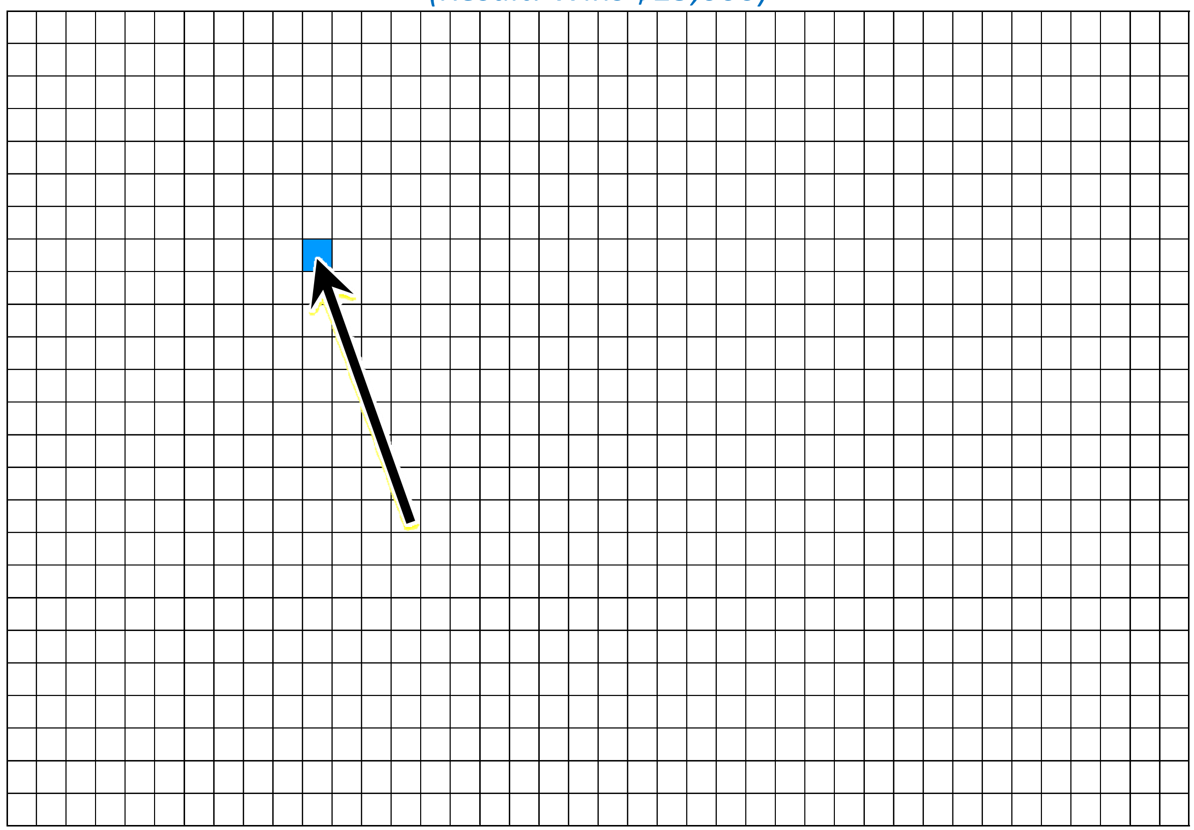


Preview to Question 8 (continued)

If the ball lands in a blue square the person will receive $25,000. Out of 1,000 spins of the roulette wheel, we would expect it to land on a blue square 1 time.

Chance of Winning $25,000 = **1** out of 1,000.

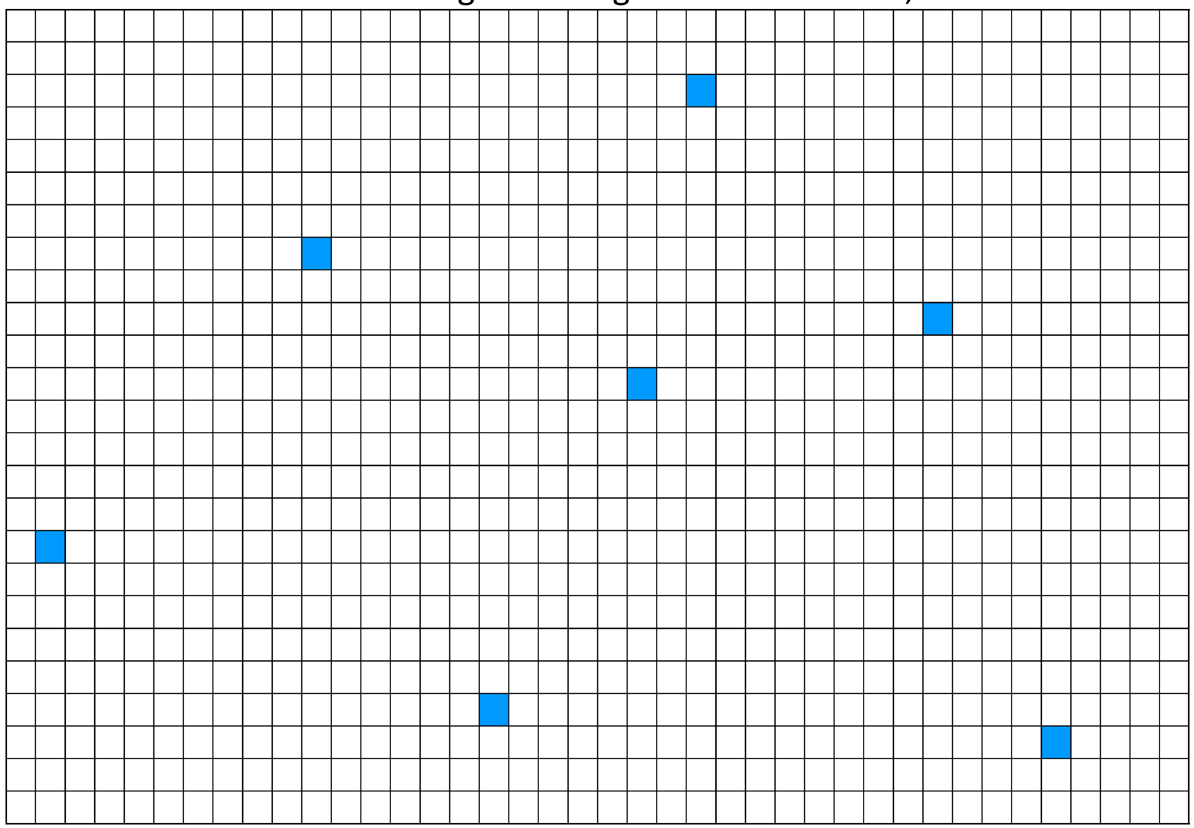
(Result: Wins $25,000)



<u>Preview to Question 8 (continued)</u>

If the person receives 7 tickets, the person's chance of winning money would be 7 chances in 1,000. This relationship can be seen in this figure.

Chance of having a winning ticket = **7** out of 1,000.



Preview to Question 8 (continued)

Suppose that the company has asked you to deal out the 10 scratch-off tickets between yourself and one other person. You are allowed to deal out the tickets in any way you choose. You can select any of the following choices:

Number given to:	
You	**Other Person**
All 10	None
9	1
8	2
7	3
6	4
5	5
4	6
3	7
2	8
1	9
None	All 10

In Question 8, you will be told the age range of the other person (for example, age 60-69), and their relationship to you (for example, “an acquaintance”). You will be asked ten versions of Question 8 (labeled 8ɸм-8ɸмл), with each version varying the age of the other person and/or the relationship of the other person to you. In each question, you will be asked to select the number of tickets (between 0 and 10) that you would like to give to yourself, with the remainder going to the other person.

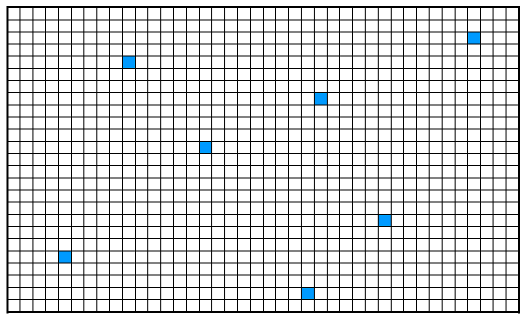
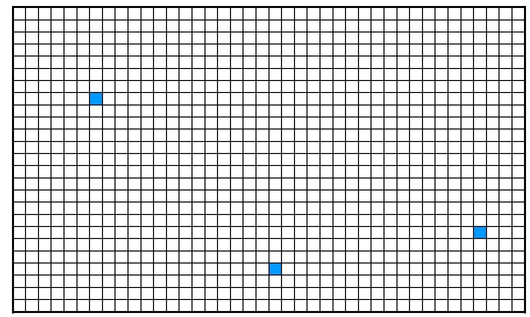
Preview to Question 8 (continued)

For each of these questions, you must enter a number between 0-10 in a blue box. The number you enter will be the number of tickets that go to you. After you do this, you will be shown the number of tickets that go to the other person, and will be shown how this donation of tickets has changed your chance of winning money and how this donation has changed the other person's chance of winning money.

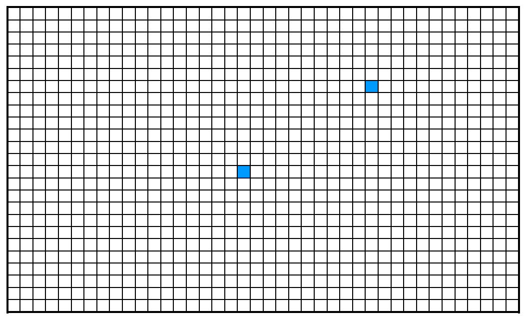
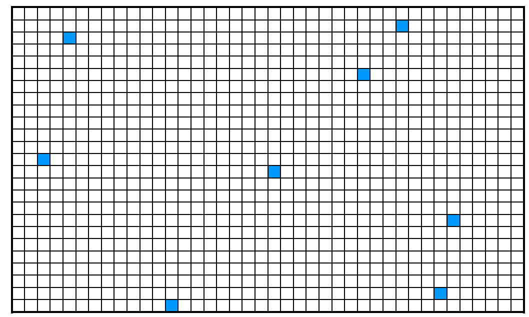
Assume that the other person will not know that you have been asked to make this choice to deal out the tickets. That is, your choice is unknown to the other person.

Before we get to Question 8, the next few questions are included to make sure you understand the concepts related to the chance of winning money from the company.

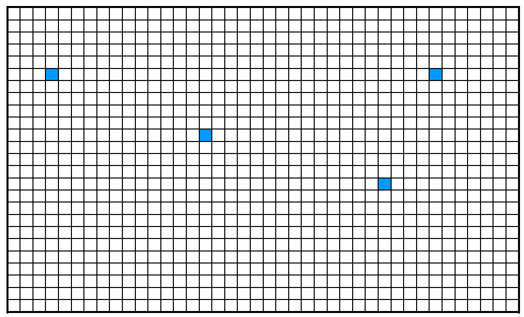
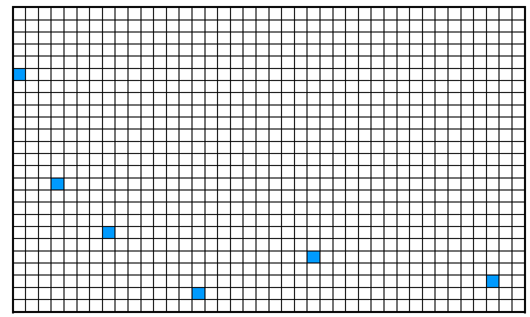
<u>Preview to Question 8</u>. Warm-Up Question A: Which person has the higher chance of having a winning ticket? Click on the box of the person who has the higher chance of having a winning ticket.

	Person 1:		Person 2:
Click on the box to select:	☐	***OR***	☐
Person receives this number of scratch-off tickets:	7		3
Baseline chance of winning $25,000 from the company:	0 in 1,000 Chance		0 in 1,000 Chance
Chance of winning $25,000 from the company ***AFTER*** tickets are given. (Blue Squares):	7 in 1,000 Chance		3 in 1,000 Chance
			
Add the following cell if they click on this person	**Correct! Person 1 has a *higher* chance of having a winning ticket than person 2.**		**Not Correct. Person 2 has a *lower* chance of having a winning ticket than person 1.**

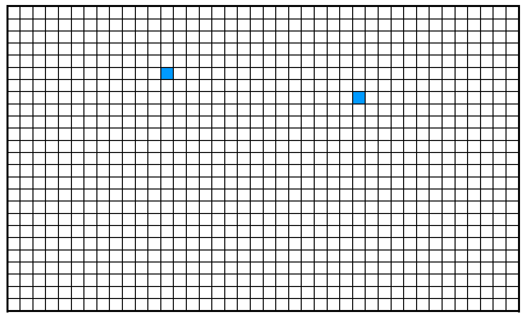
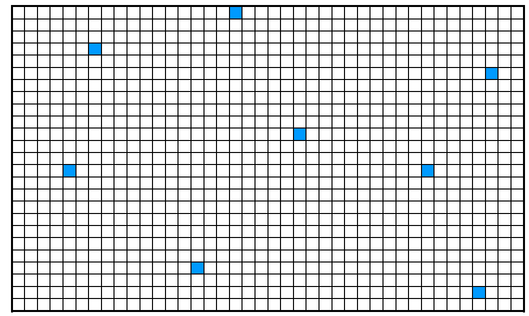
<u>Preview to Question 8</u>. Warm-Up Question A (Try Again): Which person has the higher chance of having a winning ticket? Click on the box of the person who has the higher chance of having a winning ticket.

	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Person receives this number of scratch-off tickets:	2		8
Baseline chance of winning $25,000 from the company:	0 in 1,000 Chance		0 in 1,000 Chance
Chance of winning $25,000 from the company ***AFTER*** tickets are given. (Blue Squares):	2 in 1,000 Chance		8 in 1,000 Chance
			
Add the following cell if they click on this person	**Not Correct. Person 1 has a *lower* chance of having a winning ticket than person 2.**		**Correct! Person 2 has a *higher* chance of having a winning ticket than person 1.**

<u>Preview to Question 8</u>. Warm-Up Question B: Which person would you rather be (assuming that you want to win $25,000 from the company)? Click on the box of the person you would rather be.

	Person 1:		**Person 2:**
Click on the box to select:		***OR***	
Person receives this number of scratch-off tickets:	4		6
Baseline chance of winning $25,000 from the company:	0 in 1,000 Chance		0 in 1,000 Chance
Chance of winning $25,000 from the company ***AFTER*** tickets are given. (Blue Squares):	4 in 1,000 Chance		6 in 1,000 Chance
			
Add the following cell if they click on this person	**Not Correct. Person 1 has a *lower* chance of having a winning ticket than person 2.**		**Correct! Person 2 has a *higher* chance of having a winning ticket than person 1.**

<u>Preview to Question 8</u>. Warm-Up Question B (Try Again): Which person would you rather be (assuming that you want to win $25,000 from the company)? Click on the box of the person you would rather be.

	Person 1:		**Person 2:**
Click on the box to select:	☐	***OR***	☐
Person receives this number of scratch-off tickets:	2		8
Baseline chance of winning $25,000 from the company:	0 in 1,000 Chance		0 in 1,000 Chance
Chance of winning $25,000 from the company ***AFTER*** tickets are given. (Blue Squares):	2 in 1,000 Chance		8 in 1,000 Chance
			
Add the following cell if they click on this person	**Not Correct. Person 1 has a *lower* chance of having a winning ticket than person 2.**		**Correct! Person 2 has a *higher* chance of having a winning ticket than person 1.**

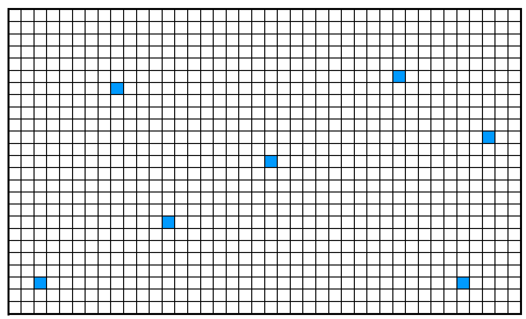
Question 8.1:

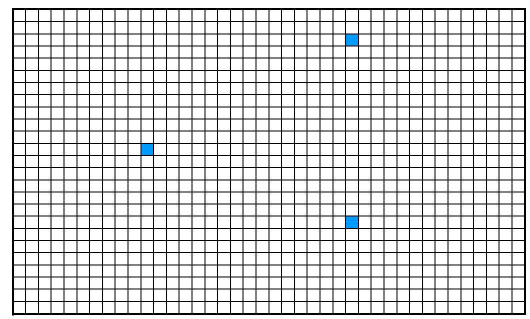
Out of the 10 scratch-off tickets that the company gives out, how many would you like the company to give to you and how many would you like the company to give to the other person? Enter the number (between 0 and 10) in the blue box that you would like to be given to you. After you enter this number, the remainder (10 minus the number given to you) will be shown in the orange box, and the number of tickets given to you and the other person will be shown as blue squares in the grid below. You may change your entry in the blue box if you are not satisfied. Once you are satisfied with your choice, click the "Continue" button.

	You **age 30-39**	**Other person is** **an acquaintance** **age 40-49**
In the blue box, enter the number of tickets you would like to go to you		
	Continue	
Baseline chance of winning $25,000 from the company:	0 in 1,000 Chance	0 in 1,000 Chance

Question 8.1:
Out of the 10 scratch-off tickets that the company gives out, how many would you like the company to give to you and how many would you like the company to give to the other person? Enter the number (between 0 and 10) in the blue box that you would like to be given to you. After you enter this number, the remainder (10 minus the number given to you) will be shown in the orange box, and the number of tickets given to you and the other person will be shown as blue squares in the grid below. You may change your entry in the blue box if you are not satisfied. Once you are satisfied with your choice, click the "Continue" button.

	You **age 30-39**	**Other person is** **an acquaintance** **age 40-49**
In the blue box, enter the number of tickets you would like to go to you	**7**	**3**
	Continue	
Baseline chance of winning $25,000 from the company:	0 in 1,000 Chance	0 in 1,000 Chance
Chance of winning $25,000 from the company ***AFTER*** tickets are given. (Blue Squares):	7 in 1,000 Chance	3 in 1,000 Chance





<u>Preview to Question 9</u>.

Question 9 is about how much you would be willing to pay for medical products and/or safety inventions that would lower your risk of dying during the next 10 years. Assume that you will use the medical products and/or safety inventions for 10 years. The amount you pay will be split into ten annual payments. For example, if you are willing to pay $1,000 in total, your annual payment will be $100 for each of 10 years.

Question 9a: Would you be willing to pay $L *in total* for medical products and/or safety inventions that would lower your risk of dying during the next 10 years by M chances in 1,000? (Your annual payment would be $L/10).

Yes ☐ No ☐

Question 9b: Would you be willing to pay $L *in total* for medical products and/or safety inventions that would lower your risk of dying during the next 10 years by M chances in 1,000? (Your annual payment would be $L/10).

Yes ☐ No ☐

Question 9c: What is the most amount of money you be willing to pay *in total* for medical products and/or safety inventions that would lower your risk of dying during the next 10 years by M chances in 1,000?

$____________ (Your annual payment would be this amount divided by 10)

OR

Question 9c: Would you be willing to pay anything at all for medical products and/or safety inventions that would lower your risk of dying during the next 10 years by M chances in 1,000?

Yes ☐ No ☐

Question 9d: What is the most amount of money you be willing to pay *in total* for medical products and/or safety inventions that would lower your risk of dying during the next 10 years by M chances in 1,000?

$___________ (Your annual payment would be this amount divided by 10)

Question 10: How would you rate your undertanding of probability?
(Click one box)

- **(A)** I do not understand probability at all
- **(B)** I have a poor understanding of probability
- **(C)** I have a fair understanding of probability
- **(D)** I have a good understanding of probability
- **(E)** I have an excellent understanding of probability

Question 11: What country or region were you born in? (Click one box)

North America

- United States of America ☐
- Canada ☐
- Mexico ☐
- El Salvador ☐
- Guatemala ☐
- Cuba ☐
- Dominican Republic ☐
- Other Country in North America (including Central America) ☐

Asia

- China ☐
- India ☐
- Phillipines ☐
- Vietnam ☐
- Other Country in Asia ☐

- Europe ☐
- South America ☐
- Africa ☐
- Australia or New Zealand ☐
- Other Pacific Island ☐
- Other Region ☐

Question 12: What state were you born in? (Click one box)

Alabama	☐	Massachusetts	☐	South Dakota	☐
Arizona	☐	Michigan	☐	Tennessee	☐
Arkansas	☐	Minnesota	☐	Texas	☐
California	☐	Mississippi	☐	Utah	☐
Colorado	☐	Missouri	☐	Vermont	☐
Connecticut	☐	Montana	☐	Virginia	☐
Delaware	☐	Nebraska	☐	Washington	☐
District of Columbia	☐	Nevada	☐	West Virginia	☐
Florida	☐	New Hampshire	☐	Wisconsin	☐
Georgia	☐	New Jersey	☐	Wyoming	☐
Hawaii	☐	New Mexico	☐	American Samoa, Guam, Puerto Rico, Virgin Islands, Other	☐
Idaho	☐	New York	☐		
Illinois	☐	North Carolina	☐		
Indiana	☐	North Dakota	☐		
Iowa	☐	Ohio	☐		
Kansas	☐	Oklahoma	☐		
Kentucky	☐	Oregon	☐		
Louisiana	☐	Pennsylvania	☐		
Maine	☐	Rhode Island	☐		
Maryland	☐	South Carolina	☐		

Appendix C: Details on Methods of Defining Social Relations Between Persons *i* and *j*

Not yet available.