NCEE Working Paper

What's in a Name? A Systematic Search for Alternatives to "VSL"

Chris Dockins, Kelly B. Maguire, Steve Newbold, Nathalie B. Simon, Alan Krupnick, and Laura O. Taylor

Working Paper 18-01
April, 2018

U.S. Environmental Protection Agency
National Center for Environmental Economics
https://www.epa.gov/environmental-economics

NCEE
NATIONAL CENTER FOR ENVIRONMENTAL ECONOMICS

What's in a Name? A Systematic Search for Alternatives to "VSL"

Chris Dockins, Kelly B. Maguire, Steve Newbold, Nathalie B. Simon,
Alan Krupnick, and Laura O. Taylor

Abstract: Benefit-cost analyses of environmental, health, and safety regulations often rely on an estimate of the "value of statistical life," or VSL, to calculate the aggregate benefits of human mortality risk reductions in monetary terms. The VSL represents the marginal rate of substitution between mortality risk and money, and while well-understood by economists, to many non-economists, decision-makers, media professionals, and others, the term resembles obfuscated jargon bordering on the immoral. This paper describes a series of seven focus groups in which we applied a systematic approach for identifying and testing alternatives to the VSL terminology. Our objective was to identify a term that better communicates the VSL concept. Specifically, a list of 17 alternatives to the VSL term was developed and tested in focus groups that culminated in a formal ranking exercise. Using a round-robin tournament approach to analyze the data, and our qualitative judgments, we identify "value of reduced mortality risk" as the dominant replacement term among the alternatives tested.

JEL Classification: Q51, J17

Keywords: value of statistical life, mortality risk valuation, terminology, focus group

What's in a Name? A Systematic Search for Alternatives to "VSL"

Chris Dockins,* Kelly B. Maguire,* Steve Newbold,* Nathalie B. Simon,[1]
Alan Krupnick,** and Laura O. Taylor***

I. Introduction

Benefit-cost analyses of environmental, health, and safety regulations often rely on an estimate of the "value of statistical life," or VSL, to calculate the aggregate benefits of human mortality risk reductions in monetary terms. Based on individuals' willingness-to-pay for small risk reductions, the VSL represents the marginal rate of substitution between mortality risk and money. This is well-understood by economists who are familiar with these concepts, but to many non-economists, decision-makers, media professionals, and others, the term resembles obfuscated jargon bordering on the immoral (Cameron 2010).

It is not hard to guess the source of confusion. In regulatory contexts, where the VSL is most commonly applied, individual reductions in future mortality risk associated with a policy—which typically are relatively small—are often aggregated over the affected population and reported in terms of "lives saved" per year. The mortality risk valuation estimates used to monetize the risk changes for a benefits analysis, derived from published stated preference and hedonic wage studies of willingness to pay for small changes in individual risk, are in turn aggregated to match the "lives saved" calculated in the risk assessment. In so doing, the notion of reporting incremental risk reductions affected through a given policy as well as their monetization is obscured. What is left to the untrained eye is the appearance of placing a value on human life using the "value of statistical life," at times leading to incredulity and consternation. Cameron (2010) discusses confusions that often surround the VSL terminology in more detail. These misunderstandings can hamper the ability to effectively communicate the impact of government policies and regulations.

The VSL terminology was first introduced fifty years ago as a marriage between interest in life-saving policy measures and the individual risks on which they are based. Schelling (1968) is credited with highlighting the fact that a policy aimed at reducing mortality may in fact "save" two lives in a city of 500,000, for example, but still only reduce individual risks by

[1] Corresponding author, National Center for Environmental Economics, US EPA, Mail Code 1809T, 1200 Pennsylvania Avenue, NW, Washington, DC 20460. Phone: 202-566-2347. Email: simon.nathalie@epa.gov.
* US Environmental Protection Agency.
** Resources for the Future
***North Carolina State University.

0.0002. Economists were not "valuing life" per se. Rather, they were estimating the number of "lives saved" (i.e., the difference between the number of expected deaths in a particular year with versus without the policy) by aggregating individual risks, and they were valuing the policy by aggregating the associated willingness-to-pay for the small reductions in risks spread over a large population. Hence, the VSL terminology was born. Banzhaf (2014) provides a detailed exposition of the history and use of the term.

The use of the word "statistical" in the VSL terminology was intended to distinguish it from the notion of a "value of life." However, as benefit-cost analysis became more commonplace in regulatory decision-making, an increase in confusion over the meaning of the term and how it is applied ensued, as discussed at length by Cameron (2010). Two incidents in particular illustrate how mischaracterization in the media contributed to widespread misunderstanding. In 2003, environmental organizations criticized the U.S. Environmental Protection Agency (EPA) for an adjustment made to the VSL in an alternative analysis intended to account for remaining life expectancy (NRDC 2003). The adjustment, dubbed the "senior death discount" by the press, was covered by a number of media outlets including National Public Radio,[2] the New York Times[3], the Wall Street Journal[4] and the Washington Post.[5] Ultimately, public protests mounted by members of the American Association of Retired Persons (AARP) prompted congressional action in the form of an amendment to the 2004 Appropriations Bill, prohibiting the EPA from making such adjustments. Congressional debate regarding the amendment did little to clarify what the EPA was monetizing with the VSL: "You may or may not agree with putting dollar values on a life, but that's what the agency does" (Senator Waxman, Congressional Record).

Similarly, an Associated Press (AP) story in 2008 entitled "An American Life Worth Less Today," reported on the U.S. Environmental Protection Agency's (EPA) use of a lower VSL estimate than it had used in the past, drawn from more contemporary, published meta-analyses of the literature. While the article provided a brief description of the risk-income tradeoffs underlying the VSL, and used the VSL term a few times, most of the language confounded valuing risks with valuing life; using statements such as "agencies put a value on human life" and "the value of life fell." The article was carried by hundreds, if not thousands, of media outlets at the time with the change even satirized in a comedy news segment by Stephen Colbert.[6] The impact of the AP article was widespread and long-lasting, spurring numerous public comments, additional confusion about "valuing life," and further threat of congressional action (Cameron 2010). While there are legitimate criticisms of these EPA analytic decisions, the fault was not with the act of monetizing small risk reductions and misunderstanding seemed to crowd out more reasoned discussion of the economics.

---

[2] Joseph Shapiro, "EPA Criticized for Plan to Reduce Value of Seniors Lives," National Public Radio's *Morning Edition,* May 5, 2003. Available at: https://www.npr.org/templates/story/story.php?storyId=1252109

[3] Katharine Q. Seelye and John Tierney. "E.P.A. Drops Age-Based Cost Studies," *New York Times*, May 8, 2003.

[4] John J. Fialka. "Chief U.S. Regulator Attempts to Find Value of Human Life," *Wall Street Journal*, May 30, 2003.

[5] Cindy Skrzycki, "Under Fire, EPA Drops the 'Senior Death Discount,'" *Washington Post*, May 13, 2003.

[6] The Colbert Report, "The Word – Priceless," July 14, 2008. Available at: http://www.cc.com/video-clips/e8zxmm/the-colbert-report-the-word---priceless.

It was in the wake of the AP article that other terms began to surface in economic analyses produced in the economics literature and by government agencies alike. Researchers introduced terms ranging from "willingness to swap" and "value of a micromort" (Cameron 2010); "value of a risk reduction" (Scotton and Taylor 2011; Hensher et al. 2011) and "value of prevented fatality" (used in European Union economic analyses) to describe the monetary value associated with risk-money trade-offs either in an attempt to avoid the mine-field associated with VSL or as a matter of policy. Even within U.S. federal agencies there is variation in terminology. For example, some analyses by the U.S. EPA refer to the "value of mortality risk" rather than VSL (US EPA, 2016) – an alternative term offered to its Science Advisory Board as one facet of proposed changes to its mortality risk valuation guidance but never formally adopted (USEPA 2010b). While part of the motivation behind the use of these alternatives may be to employ more intuitive and less provocative terminology than VSL, to the best of our knowledge these alternative terms are based on researcher or analyst intuition about what "sounds good." There is no information to indicate a more robust or scientific process was used to derive any of these alternative terms and likewise no indication that any of them would perform better than VSL. Indeed, EPA's SAB cautioned against adopting new terminology in the absence of further testing "to explore the language that best communicates this concept to the public" (USEPA 2011).

In this paper we apply a systematic approach for identifying and testing alternatives to the VSL terminology. The main objective is to identify a term that may better communicate the concept of a marginal rate of substitution between mortality risk and money to a broad group of people, including members of the general public. Using results from a series of focus groups and consultations with stakeholders, we develop and test a list of viable options. This paper describes the process we follow and the replacement terms that emerge from our results. Section II describes the methodology used to develop and examine alternative replacement terms including a summary of the focus groups and ranking exercises; and Section III describes the analysis of the ranked data, followed by a discussion of our evaluation of alternative terms in Section IV. Section V concludes and adds a discussion of the limitations of our approach, and possible additional steps that could be taken to further vet any new terminology before it is broadly applied.

II. Methods

We employed a suite of methods to identify an alternative term or terms to the VSL starting with focus group results and finishing with a ranking exercise of options that were identified by focus group participants and experts. The focus groups were generally structured so as to start with a general discussion, and then proceeded with an increasingly more focused discussion as participants provided input on new terms and reactions to existing ones. At the conclusion of the seven focus groups, we conducted a ranking exercise to identify preferred terms using quasi-quantitative tools.

Focus groups are generally useful for providing a broad exploration of topics for which little empirical or quantitative information exists. Within the economics literature, for example, the use of focus groups and cognitive interviews typically precedes stated preference survey design. In this study, budget and other constraints precluded the implementation of a full survey of a random sample of individuals. However, the use and qualitative assessment of the results provide relevant information for identifying alternatives to the VSL terminology.

Our research design proceeded as follows. First, we conducted three focus groups with members of the general public to systematically identify alternative terms. We then conducted four focus groups with a convenience sample of non-economists employed at the U.S. EPA to rank the alternative terms that were identified in the focus groups with the general public. We develop our recommendations from an assessment of the preference rankings. Each step is described in more detail below.

A. Public focus groups (Focus Groups 1-3)

We conducted a series of three focus groups in February 2017 in the greater Washington, DC metropolitan area with members of the general public to develop and examine alternatives to the VSL terminology.[7] Each group consisted of 9 to 10 participants, aged 21 years of age or over. Participants were recruited to provide an even split across genders, with broad racial representation. While participants in the first focus group were limited to individuals with a bachelor's degree or higher, this minimum education criterion was relaxed for the second and third focus groups. Table 1 provides a summary of the demographic characteristics of our public focus group participants compared to the U.S. population. As indicated, focus group participants tended to be older, more racially diverse, and with higher incomes compared to the U.S. population. All focus groups were moderated by members of the research team who have professional experience in moderating group discussions.

Table 1: Demographic Characteristics, Focus Groups 1-3

	Mean	U.S. population[8]
Age	58	37.9 (median; entire population in 2016)
Gender	54% female	50.8% female
Race	46% non-White	13.1% non-White
Education	89% some college education	60.1% some college education
Income	$97,384[9]	$55,322 (median)
N[10]	26	

[7] Approval for the conduct of the public focus groups, required under the Paperwork Reduction Act, was provided by OMB on January 24, 2017. OMB control number 2090-0028; expires 9/30/2018.
[8] U.S. Census Bureau, Quick Facts for 2017 unless otherwise noted.
[9] Average income is based on the mid-point of range categories.
[10] There were 29 participants across Focus Groups 1-3. However, we lack demographic information for 3 participants.

Focus Groups 1 and 2

Following introductions, each focus group included a warm-up activity to familiarize participants with the subject matter. Participants in Focus Groups 1 and 2 were asked to read a modified version of a *Wall Street Journal* article titled "Rail Safety and the Value of Life," which discussed tradeoffs between money and risk for a rail transportation project and specifically used the term "value of statistical life" (see Appendix A).[11] The purpose of this exercise was to learn how non-economist readers interpreted the term when encountered in a non-technical publication. We intentionally selected an article that discussed fatal transport accidents rather than environmental risks so that the discussion could focus on wealth-risk tradeoffs without complications from co-morbidities or environmental policy.[12] We then led the participants in a discussion about the article in general, what they thought about making trade-offs between money and risk, and how they interpreted the VSL term.

Participants had questions about the article and wanted more information about the probability of dying from proposed rail transportation projects. Specifically, they posed questions about the frequency of rail use, costs associated with project implementation, and prioritization of various alternatives. When asked about the terminology, some participants accepted that money-risk trade-offs are a necessary ingredient (e.g., "…in order to do an analysis of anything you need to attach a value to it"). Others thought that all of the programs should be pursued, rejecting the idea that any risks could be tolerated ("…they should just allocate the money….and start repairing things all over the country that need to be done"). Notably, several participants equated the estimate in the article to the value of a specific life ("…they were equating one individual life to be worth $9.1 million").

We then turned to the portion of the article focusing on the VSL terminology. Most participants indicated a general familiarity with the basic concept, with some relating it to actuary tables that are used in setting insurance rates or used in wrongful death suits. There was some discussion about whether the value would vary if people are willingly taking on a risk (e.g., parachuting out of an airplane) versus taking a risk for which they have less control (e.g., using a train to commute). Through this discussion most understood that the term, as it was used in the *Wall Street Journal* article, reflected an average value across many individuals and not the value for a specific individual, although some thought the concept could be intentionally misleading or confusing. "…the core issue is value of life. But that's a very emotional thing to say. So they call it…value of statistical life because it (is) more of an abstract concept." The group wanted to know more about how the value was calculated. One participant pointed out that the article indicates that the value represents how much people value lowering the risk of death. "So, it's not about life. It's about lowering the risk of death….and what we are willing to spend for not dying." Even so, some found the term confusing. One participant stated, "I thought it was a number that was… out of the air." And,

[11] In particular, the original article was reduced from about 2300 words to just over 500, and the discussion was focused on the definition and use of VSL.

[12] In this regard we are consistent with the basis of virtually all guidance on valuing mortality risk for policy analysis, which are generally based on hedonic wage studies of workplace accidents or stated preference studies where risk reductions are often associated with transportation risks (e.g., car accidents) or are framed in more generic terms divorced of any specific context (Robinson, 2007).

“[T]here also seems to be a kind of twisted assumption that by spending money I can save lives…” Also, “[I]t’s a little confusing.”

Participants in Focus Group 1 expressed an interest in knowing more about the VSL calculation, so in Focus Group 2 we introduced a short summary (see Appendix B). We specifically chose an example that addressed safety, but again was unrelated to environmental exposures—provision of lifeguards at public beaches. While it helped participants understand the concept of VSL, the example itself became an unintended focus of the discussion, with the conversation turning to recreation choices and how to avoid drowning.

In Focus Groups 1 and 2, we asked participants to provide terms they thought might better describe the VSL concept.[13] Terms included:

- Accident reduction cost
- Cost of risk reduction
- Cost risk analysis
- Health risk valuation
- Investment risk analysis marginal utility (of something)
- Marginal safety risk
- Mortality risk reduction benefit
- Preventative cost expenditure
- Price of mortality risk reduction
- Risk reduction cost
- Risk reduction value
- Risk reduction value benefit (or analysis)
- Safety risk variable/valuation
- Safety/Health benefit cost
- Value of fatality prevention
- Value of mortality risk reduction
- Value of risk reduction[14]
- Willingness to pay for a service at a level of safety
- Willingness to pay for services
- Willingness to spend money to reduce the risk of dying

[13] Throughout the focus groups we remained agnostic about the “units” associated with candidate terms. That is, we did not constrain the choices to ones that would only be associated with a “life” or conversely, units that would only be associated with actual risk reductions (such as, say, a 1-in-1,000,000 reduction in the risk of dying or micro-mort). One feature of the VSL that may reinforce the impression that it represents the value of “whole lives” is its implied measurement units, which are dollars per mortality per year. Alternative terms that are agnostic about measurement units would remove this erroneous connotation and the measurement units could then be selected flexibly on a case by case basis.

[14] This term is similar to that suggested by the Environmental Economic Advisory Committee of EPA’s Science Advisory Board (SAB-EEAC). The SAB-EEAC 2017 report includes: “The SAB finds that a term such as “Value of Risk Reduction for Mortality” (VRRM) may be a better term than “Value of Statistical Life” (VSL) for communication with non-economists.” (US EPA 2017).

Participants also identified specific words they preferred be part of the term for the risk-money tradeoff, including "risk," "reduction," and "cost." Participants specifically wanted to omit the words "value" and "life" because "those are very emotional discussion points." Perhaps for similar reasons, the term "death" did not feature prominently in their discussion of preferred terms. But, they also recognized that alternatives might "lead people not to realize what they are talking about." Other words participants thought should be avoided included "marginal" and "price."

In Focus Group 2 after participants suggested terms, they voted on their preferred term and identified "safety risk valuation" as the group favorite. Overall, participants in this group had more difficultly with the concept and suggesting alternative terms than participants of Focus Group 1, but ultimately were able to offer input on words they found more or less descriptive.

Focus Group 3

In Focus Group 3, we made a small modification to the *Wall Street Journal* article and substituted the VSL term in half the articles provided to participants with an alternative—"mortality risk reduction benefit," or MRRB—a term suggested in the previous two focus group discussions that seemed to satisfy the preferences we heard in both groups. It included the words "risk" and "reduction" to indicate direction, "mortality" to elicit less of an emotional reaction, and "benefit" as this seemed to resonate among the participants as a better substitute than words such as "value" and "price." Some Focus Group 3 participants who received the version with MRRB seemed to understand what was being communicated. "…they're trying to figure out what the risk of death and what the benefits are from that." On the other hand, some participants found it to be too technical. "…[F]or the average public I don't like reading those kinds of words" and "…sounds like you're in economics class…" Others had negative reactions to the concept. "To me it sounded a little bit cold when talking about human lives." For those who had the VSL version of the article the reactions were similar. "I don't like the word statistical."

We then presented each participant with a random selection of five alternative terms from a list of terms identified in the previous two focus groups. The choices varied across the handouts to obtain information on a wide variety of options. For example:

> For this purpose, the federal government has adopted a measurement known as the "________________________"
>
> —roughly speaking, the amount of money Americans are willing to spend for reductions in the risks of death.

marginal value of a risk reduction

benefit of mortality risk reduction

risk reduction value

value of mortality risk reduction

risk reduction unit benefit

We then asked each participant to rank their top three terms based on which they thought most clearly and accurately conveyed the concept.

Across the focus group participants there was wide variation in the first-choice terms. Recall, each participant had a different set of terms, so variation is expected. The top ranked terms along with some of the reasoning in parentheses are as follows:

- willingness to pay to reduce the risk of death ("…simple words… and straight to the point…")
- value of prevented fatality ("…simple, clear, done…" "…value is more positive…")
- value of mortality risk reduction ("…I preferred ...a technical term versus an emotional term… [not] anything related to fatality, life…")
- benefit of mortality risk reduction ("…straightforward…non-emotional…")
- benefit of reducing risk ("…plain, simple…")
- marginal value of risk reduction
- risk reduction value
- population willingness to pay to reduce death risks.

During a break, we tallied the information across the participants and presented the group with their aggregated rankings across the group. We then guided the group through an iterative process of removing the term that had received the least number of votes and then re-ranking the remaining terms as the list was narrowed. As the discussion progressed, participants seemed to reach agreement that the term should include something about the nature of the risk, such as "mortality" or "fatality," and not just the word "risk" generically. In addition, they felt an action word should be included, such as "prevented" or "reduced." After some discussion, the participants came to understand that policy decisions do not "prevent [specific] fatalities" but rather reduce their risk. They closed the discussion by focusing on the monetary component. Should "value," "willingness to pay," "benefit," or some other word or phrase be used to represent this aspect of the concept? Ultimately, the group agreed (by majority consent if not consensus) that "value of reducing fatality risk" was the most descriptive and comprehensible term.

Conclusions from Focus Groups 1-3

We drew three main conclusions from the results of the general public focus groups. First, the words "value," "statistical," and "life" taken together are not preferred by most respondents; they do not accurately describe the concept being conveyed to the general public. The words "value" and "life" provoke an unintended emotional response and suggest one is valuing a specific, individual life. Second, the term ultimately chosen should be concise, but clear and relatively non-technical. Finally, the term should include words that describe the monetary component, convey the fatal nature of the risk, and indicate the risk is being reduced not prevented.[15]

[15] Technically, what matters is that the term indicates a change in risk which is, in principle, positive or negative. Our primary focus is on risk-reducing policies, but there can be risk increases associated with policy actions as well. We return to this point in the concluding discussion.

B. *Systematic development of alternative terms*

Informed by the focus groups with the general public, we revisited and revised the list of candidate replacement terms, requiring that each term include words to describe three important constituent or "building block" concepts:

- Monetization;
- Endpoint being valued (i.e., mortality risks); and
- Small change in risk associated with the endpoint, not the elimination of risk.

We began by developing lists of terms that fit into each category and then asked experts within EPA to provide (1) feedback on the terms in each category (e.g., were any missing or unacceptable), (2) a ranking of the terms developed from the building blocks, and (3) any additional terms that should be considered.

Table 2 provides the final list of monetization building block words we considered. We assessed each of the monetization words on three factors: (1) whether it was already used in the context of benefit cost analyses so as to be potentially confusing; (2) whether it was stated in plain language (i.e., less jargon-filled); and (3) whether it had been identified in Focus Groups 1-3 as viable. Check marks in Table 2 indicate the term "passes" the criteria (i.e., does not have a rival use in BCA, represents plain language, and/or accepted by focus group participants). To narrow the list, we started by eliminating those with rival uses in economic analyses. For example, "investment" typically conveys use of money in exchange

Table 2. Monetization building blocks

Term	**No rival use in BCA**	**Plain language**	**Accepted by Previous Focus Groups (1-3)**
Value	✓	✓	✓
Benefit	✓	✓	✓
Willingness to pay	✓		✓
Willingness to spend	✓		✓
Willingness to swap	✓		
Willingness to accept	✓		
Cost		✓	✓
Expenditure		✓	✓
Investment		✓	✓
Price		✓	✓
Implicit price			
Shadow price			

for some type of monetary profit. And, “expenditure” usually refers to payment for some type of good or service. We consider these to be uses of the term that could complicate their use in describing trade-offs between money and risk. Of the remaining terms, we only retained those that were in “plain language” or had been identified in the previous three focus groups as acceptable. Based on these assessments, we determined that “value,” “benefit,” “willingness to pay,” and “willingness to spend” were the most suitable candidate phrases for the monetization component of the candidate replacement terms.

Table 3 shows the endpoint building block words we considered. We assessed each option on (1) whether it reflects the endpoint of interest (i.e., death and its synonyms/antonyms); (2) whether it captured the statistical component; and (3) whether it was in plain language. We only retained those options that satisfied all three factors. In short, we found that “probability,” “chance,” and “risk” best reflect the statistical component of the term. “Death,” “dying,” “mortality,” “fatality,” and “survival” seem to best reflect the endpoint. We also found in many cases that the ordering of the statistical component and the endpoint mattered, and favored the statistical component coming before the endpoint for its improved fluidity (i.e., probability of death as opposed to death probability). This was a subjective judgement based on our own assessment of what was likely to be considered a more common ordering of terms. We explore this latter point more fully below as we discuss the next set of focus groups.

Informed by the focus group discussions, we decided that including the direction of the change in the terminology enhances clarity of the term and corresponds more directly to the nature of the changes that are typically associated with most regulations. The fundamental concept the term should capture is the value associated with a change in risk or survival probability, so it seems reasonable to include this notion in our terminology. That is, “reduce,” “reduction,” or “decrease” match the fact that governmental policies are generally designed to reduce risks or improve survival probability. While we recognize that there may be instances in which governmental action increases some risks, such as in the case of offsetting risks, or in deregulatory settings, we nevertheless contend that including a directional component in a new term is important to improving the clarity of the term for most scenarios. In addition, we assessed whether the “change” term was applicable to regulatory scenarios, that is, whether it could be paired in a meaningful way with the endpoint. We eliminated several words that we determined would be misleading, including “prevent,” “prevention,” “save,” and “averting,” in that they seemed to convey a total elimination of the risk rather than an incremental reduction. Table 4 shows the “change” terms we considered.

Table 3. Endpoint Building Blocks

Term	Endpoint of Interest	Statistical Component	Plain Language
Probability of death	✓	✓	✓
Chance of death	✓	✓	✓
Risk of death	✓	✓	✓
Probability of dying	✓	✓	✓
Chance of dying	✓	✓	✓
Risk of dying	✓	✓	✓
Probability of mortality	✓	✓	✓
Chance of mortality	✓	✓	✓
Risk of mortality	✓	✓	✓
Probability of fatality	✓	✓	✓
Chance of fatality	✓	✓	✓
Risk of fatality	✓	✓	✓
Probability of survival	✓	✓	✓
Chance of survival	✓	✓	✓
Risk of survival		✓	✓
Death probability	✓	✓	
Death chance	✓	✓	
Death risk	✓	✓	
Dying probability	✓	✓	
Dying chance	✓	✓	
Dying risk	✓	✓	
Mortality chance	✓	✓	
Fatality chance	✓	✓	
Mortality probability	✓	✓	
Fatality probability	✓	✓	
Mortality risk	✓	✓	✓
Fatality risk	✓	✓	✓
Survival probability	✓	✓	✓
Survival chance	✓	✓	✓
Survival risk	✓	✓	✓
Premature death	✓		✓
Health risk			✓
Longevity			✓

Human life	✓		✓
Mort	✓		
Services			✓
Accident			✓
Safety			✓
Life	✓		✓

Table 4. Change building blocks

Term	Conveys Direction	Applicability
Reduce	✓	✓
Reduction	✓	✓
Decrease	✓	✓
Improvement	✓	✓*
Changing		✓
Change		✓
Prevent		
Prevention		
Save		
Averted		

Notes: * Only if paired with "survival"

Finally, we considered several other terms that identify the magnitude of the change. We regarded these as optional, but they were included in some of the candidate terms. The magnitude words we retained for consideration are:

- Micro
- Milli
- Marginal
- Small
- Incremental
- Standardized unit

Using the building blocks in Tables 2-4, we constructed a set of candidate replacement terms by assembling various combinations of "monetization," "endpoint," and "change" components. In some cases, a "magnitude" component was also included. The list of candidate terms in Table 5 does not exhaust all possible combinations because these are far too numerous to be manageable in a focus group setting. In selecting these 17 terms from the larger set of possibilities, we tried to achieve a reasonably balanced representation of most or all components listed in Tables 2-4 above, while omitting those we thought would have a high likelihood of being dominated by other terms on the list.

Table 5. Candidate terms (and acronyms) as an alternative to VSL

Term	Acronym
Value of Mortality Risk Reduction	VMRR
Value of Reduced Mortality Risk	VRMR
Value of Reduced Fatality/Fatal Risk	VRFR
Value of Decreased Mortality Risk	VDMR
Value of Mortality Risk Change	VMRC
Value of Micro Risk Reduction (for mortality)	$VMRR_{mortality}$
Value of a Standardized Risk Unit (for mortality)	$VSRU_{mortality}$
Value of Reduced Risk (of mortality)	$VRR_{mortality}$
Value of Reduced Chance of Death/Dying	VRCD
Value of Improved Probability of Survival	VIPS
Value of Improved Chance of Survival	VICS
Willingness to Pay for Decreased Mortality Risk	WTP_{DMR}
Willingness to Pay for Reduced Mortality Risk	WTP_{RMR}
Marginal Benefit of Mortality Risk Reduction	MBMRR
Marginal Value of Mortality Risk Reduction	MVMRR
Benefit of Micro Risk Reduction	BMRR
Willingness to Spend for Mortality Risk Reductions	WTS_{MRR}

As noted above, the lists of building block terms and our revised list of candidate terms were shared with eight senior staff economists representing various offices across the EPA for input prior to the EPA focus groups. Specifically, these experts were asked to review each list, identify building blocks and candidate terms they felt should be added or removed, and to provide justification for their suggestions. At the conclusion of their reviews, these experts suggested no new building block words, but did identify two additional terms for consideration in the focus groups: "willingness to pay for mortality risk reduction" and "unit benefit of mortality risk reduction." Input from these same experts led us to remove four terms from further consideration: "value of reduced fatality/fatal risk," "value of reduced chance of death/dying," "value of improved probability of survival," and "willingness to spend for mortality risk reduction." The final list emerging from these consultations contained 16 terms, including the value of statistical life.

We subsequently learned that contributors to the Guidelines for Benefit-Cost Analysis project, organized by the Harvard School of Public Health and funded by the Bill and Melinda Gates Foundation, were considering using the term "value of a standardized mortality unit" in lieu of "value of a statistical life." We chose to add this term to our list for further testing, bringing our list of candidates back up to 17 terms.[16]

C. EPA employee focus groups (Focus Groups 4-7)

To evaluate the 17 terms, we organized a second round of focus groups. All participants in these focus groups were EPA employees, but none were professional economists or analysts who regularly work on economic analyses. The only other requirement we imposed was that participants should hold a Bachelor's degree. We recruited EPA staff members by (1) request to other economists within the Agency to suggest staff who fit the inclusion criteria (i.e., were not economists and did not work on benefit-cost or regulatory impact analyses); and (2) through personal contacts of the research team. We recognize that this convenience sample is not representative of the general population and a few participants did acknowledge concerns unique to EPA (e.g., how terms related to other regulatory language or reporting conventions)., Still, we believe that the preferences and opinions of this sample provide useful input for our deliberations regarding the 17 candidate terms.

Focus Groups 4 through 7 were held at EPA Headquarters in Washington, DC in August and September 2017. Focus Groups 4, 5, and 6 included ten participants each, and Focus Group 7 included six participants. Participants were recruited using personal contacts across the agency. Specifically, we asked contacts to provide suggested names of colleagues or staff who met the following criteria: non-economists who did not conduct or use benefit-cost analysis in their daily work and held a Bachelor's degree or higher. We did not collect any additional demographic information on participants in oder to maintain as much privacy and anonymity as possible since it was conceivable we would encounter these participants in other work-related settings.

The format of this series of focus groups was different than the first three focus groups with members of the general public. We condensed the presentation and background section to focus on the critical elements of the exercise in part to reduce the length of the focus group to 60 minutes. Each focus group began with a 10-minute presentation and discussion of mortality risk reductions and trade-offs between money and risk. Following the introductory material explaining the concept of reducing risks and communicating valuation information, each participant was provided a set of 17 index cards and was asked to rank the cards according to his or her judgments about how accurately and clearly the terms conveyed the target concept. The specific details of the ranking exercise varied slightly across the four focus groups.

Focus Groups 4-6

In Focus Group 4, we asked participants to indicate their rankings by placing the 17 cards on the table in front of them in order vertically from most preferred to least preferred, with ties represented by placing the cards in the same row. We then discussed how and why each participant ranked the outcomes as they did. The "value of statistical life" was included in

[16] More information about the Harvard School of Public Health Benefit Cost Analysis Guidelines project can be found at https://sites.sph.harvard.edu/bcaguidelines/.

the list of terms, but we did not reveal to participants that this was the term currently in use. Instead, we included it without comment amongst the terms they were asked to rank. Next, we provided participants with a green strip of paper and asked them to place it among their ranked cards such that they judged the terms above the strip to be "acceptable" and those below the strip "unacceptable." All but one of the participants placed the terms that began with "willingness to pay" or "value of reduced mortality…" at or near the top of their ranked list. Terms with "marginal" or "standard unit" and "value of statistical life" most frequently appeared below the participants' green lines (i.e., were identified as unacceptable). One participant who preferred the "marginal value" terms also included "value of reduced mortality risk" near the top of their list of preferences. Participants rejected the terms with statistical jargon because they felt these terms were more difficult to understand. Most participants ranked VSL at or near the bottom of their list.

Focus Groups 5 and 6 proceeded similarly except that VSL was initially excluded from the list of options. After participants ranked the terms and placed the green line to demarcate acceptable versus unacceptable terms, we gave them a card with "value of statistical life" and revealed that this was the currently used term. We then asked them to place "value of statistical life" where they thought it ranked among the other terms. In these groups, participants consistently ranked "value of improved chance of survival" or a version of "value of reduced mortality risk" near the top. Participants preferred these terms because they were less "sciencey" or "jargony" and simpler. VSL consistently ranked at or near the bottom. One participant said the VSL seemed "hypothetical." Participants described the terms with "unit," "micro," and "standard" as "too awkward" and "cold." One participant noted that they preferred the word "death" to "mortality." Another said they did not like the word "survival" because it sounds like "we are on a sinking ship."

Focus Group 7

After reviewing the results from Focus Groups 5 and 6, we became concerned that the terms presented to participants were imbalanced in that only one contained "survival" while most of the others contained "mortality" or something similar. Those who preferred "survival" had only one term to choose from while those who preferred "mortality" were able to split their vote among many similar alternatives. Therefore, we developed a modified set of candidate terms for participants to rank in Focus Group 7. This modified list was intended to provide a more balanced set of terms, including alternatives to "mortality" (e.g., death, fatality) and more options containing "survival."

The set of terms used in Focus Group 7 were:

- Value of decreased mortality risk
- Value of decreased fatality risk
- Value of decreased risk of death
- Value of increased survival probability
- Value of mortality risk reduction
- Value of fatality risk reduction

- Value of reduced risk of death
- Value of survival probability improvement
- Value of reduced risk of mortality
- Value of reduced risk of fatality
- Value of reduced chance of death
- Value of improved chance of survival

Following the same procedure as Focus Groups 4-6, participants provided their initial rankings, positioned the line demarcating acceptable and unacceptable terms, and then placed the current VSL term among them. We then asked the participants to consider the remainder of the terms that were used in Focus groups 4-6. Participants considered each and included those terms they found acceptable among their ranked terms.

Considering their full rankings, participants in Focus Group 7 appeared to prefer terms that provided a more positive connotation, like “survival,” and preferred “mortality” over “fatality” and “death.” One participant thought the terms “mortality” and “fatality” were aimed toward someone with a higher education and the terms with “marginal” and “standard” sounded too much “like math.” Another participant noted that they liked the terms that include “mortality” because they would be consistent with other documents, like a risk assessment, that would be included with the information accompanying a given regulation aimed at reducing risks. Several participants indicated that they preferred terms with simpler acronyms, recognizing that such an acronym would often be used rather than the full term.

III. Analysis of focus group preference rankings

Focus Groups 4-7 produced 36 complete rankings of a common set of 17 candidate replacement terms. For purposes of analyzing the data, we recorded each focus group participants’ preference rankings (without individual attribution) using the following protocol: Terms were scored from 1 to *n* above the green acceptability line and from -1 to –*m* below the line.

We analyzed these scores using a round-robin tournament approach, which involves head-to-head comparisons of all pairwise combinations of the 36 terms using the scores for all participants to infer majority-vote winners (see Appendix C for details). The round-robin tournament was used to identify dominant (sets of) terms, which are those terms that defeat all other terms not in the dominant set in a head-to-head vote. If only a single term comprises the dominant set, then no voting cycles are possible. If more than one term comprises the dominant set, then a voting cycle is possible and so a single candidate that is “preferred by the group” cannot be definitively identified from among the terms in the dominant set.

The results of the candidate term preference ranking analysis are shown in Tables 6 through 8. Table 6 includes three sets of results for the 17 candidate terms that were ranked by all

Table 6. Focus Groups 4-7 ranking aggregation results, using original set of 17 terms.

		w/ FG7	w/o FG7	w/o VICS
1	Benefit of micro risk reduction	0	0	0
2	Marginal benefit of mortality risk reduction	0	0	0
3	Marginal value of mortality risk reduction	0	0	0
4	Unit benefit of mortality risk reduction	0	0	0
5	Value of a standard mortality unit	0	0	0
6	Value of a standardized risk unit (for mortality)	0	0	0
7	Value of a statistical life	0	0	0
8	Value of decreased mortality risk	0.018	0.03	*0.276*
9	Value of improved chance of survival	**0.962**	**0.825**	--
10	Value of micro risk reduction (for mortality)	0	0	0
11	Value of mortality risk change	0	0	0
12	Value of mortality risk reduction	0.008	0.019	0.017
13	Value of reduced mortality risk	*0.066*	*0.246*	**0.814**
14	Value of reduced risk (of mortality)	0.011	0.019	0.122
15	Willingness to pay for decreased mortality risk	0.001	0.001	0.015
16	Willingness to pay for mortality risk reduction	0	0	0
17	Willingness to pay for reduced mortality risk	0.001	0.001	0.015

Notes: Bold cells indicate members of the dominant set. Italics indicate the second most favored term. Values indicate the frequency that each term is a member of the dominant set based on re-sampling individual rankings with replacement. The first column of results based on Focus Groups 4-7. The second column excludes Focus Group 7. The third column excludes "value of improved chance of survival."

participants of the EPA focus groups. The terms that are members of the dominant set are indicated by a bold font number in the corresponding row.

To examine the robustness of our results, we used a bootstrap approach (Efron 1979) to estimate the frequency that each candidate term would appear in the dominant set in repeated studies with the same sample size of focus group participants. The numbers in each row indicate the frequency that each candidate term was a member of the dominant set among 10,000 bootstrap samples of focus group participant rankings drawn with replacement from the original dataset. For example, "value of improved chance of survival" was in the dominant set in 96.2 percent of the bootstrap samples. The first column of results is based on Focus Groups 4-7. The second column excludes Focus Group 7, because this group followed a slightly different protocol than the other three EPA focus groups, as explained above. The third column includes data from Focus Groups 4-7 but excludes "value of improved chance of survival (VICS)," to examine how the other terms ranked when the dominant term was removed. In the first and second cases, "value of reduced mortality risk" (VRMR) was the second most frequent term in the dominant set. When VICS was excluded from consideration, VRMR was the most frequent term in the dominant set.

Table 7 complements these results, showing the frequency distribution of the size of the dominant set of terms among the bootstrap samples. In a large majority of the 10,000 bootstrap samples, 96.5 percent, the dominant set included only one candidate term. In 1.7 percent of the bootstrap samples the dominant set included two candidate terms. In 91 percent of these cases (153 out of 168 bootstrap samples), the members of the dominant set were "value of improved chance of survival" and "value of reduced mortality risk." In 95 percent of all bootstrap samples where the dominant set included more than one candidate term (314 out of 332 bootstrap samples), "value of improved chance of survival" was a member of the dominant set.

Table 8 includes results for the second set of 12 candidate replacement terms that were ranked only by participants of Focus Group 7. "Value of improved chance of survival" is the sole member of the dominant set in this case as well. However, in this case the estimated frequencies of dominant set membership are larger and more evenly distributed among the remaining 11 terms. The second highest frequency of membership in the dominant set (in italics) is "value of reduced risk of death," but, as noted above, the second-best performer in Focus Groups 4-7 is "value of reduced mortality risk."

Table 7. Frequency distribution of the size of (number of candidate terms in) the dominant set among the bootstrap samples.

Dominant set size	Frequency
1	0.967
2	0.017
3	0.007
4	0.003
5	0.005
6	0.001

Table 8. Focus Group 7 ranking aggregation results, using new set of 12 terms.

		FG7
1	Value of decreased fatality risk	0.254
2	Value of decreased mortality risk	0.256
3	Value of decreased risk of death	0.279
4	Value of fatality risk reduction	0.223
5	Value of improved chance of survival	**0.822**
6	Value of increased survival probability	0.363
7	Value of mortality risk reduction	0.249
8	Value of reduced chance of death	0.279
9	Value of reduced risk of death	*0.375*
10	Value of reduced risk of fatality	0.256
11	Value of reduced risk of mortality	0.230
12	Value of survival probability improvement	0.193

IV. Synthesis and Discussion

"Value of improved chance of survival" (VICS) was the only dominant term from the systematic rankings made by participants in Focus Groups 4-7, suggesting that it may most effectively convey the risk-income tradeoff concept to non-economists within the EPA. However, no participants in Focus Groups 1-3, which included members of the general public, suggested this or any similar terms framed as improvements in survival probability, which suggests it may be less well-suited for communicating across a broader spectrum of people.

In addition, the term "improved chance of survival" is often used as a term of art in other contexts, which may lead to unintended confusion. For example, many scholarly articles in health-related fields refer to "improved chance of survival" as an outcome metric when comparing treatments for life-threatening conditions, most often related to overcoming disease or injury or improving access to health care. Any search for the exact term will show hundreds of articles per year in the medical literature covering topics from survival of severely ill infants (Aramburo, et al. 2017) to CPR use (Fukuda, et al 2016) to battlefield resuscitation (Davis, et al 2017). What much of this literature has in common is a focus on treatments to increase survival probability for those already suffering substantial mortality risk or severe health detriments. The VSL – and any preferred replacement term – is generally applied for marginal risk reductions from a relatively small baseline.

Another, less common, source of potential confusion is the use of the term "improved chance of survival" in legal parlance related to the "loss of a chance" (or "lost chance") doctrine as applied in medical malpractice. The *Oxford Handbook of US Health Law*, for example, explains this loss of a chance doctrine using the terminology "…the loss of an improved chance of survival…" (Furrow 2016, p 428). In light of these considerations, we have some concern that using "value of improved chance of survival" in place of "value of statistical life" could merely trade one set of confusions with another, through unintended associations with distantly related medical or legal concepts. Adding these additional considerations to the qualitative findings from Focus Groups 1-3, it is not clear to us that "value of improved chance of survival" is preferable to the other terms.

If we consider alternatives after removing VICS from the list of candidate terms, "value of reduced mortality risk" (VRMR) is the dominant term from the systematic rankings.[17] VRMR is similar to terms that were more frequently preferred in Focus Groups 1-3 (e.g., "value of mortality risk reduction," "value of reducing fatality risk"), suggesting that it could prove effective in communications aimed at a broad spectrum of the general public, including those without an economics background and individuals not employed by the EPA. In addition, this term does not appear to be used as a term of art in other domains or have a specific legal definition that might lead to unintended confusions. Another potential advantage of this term is its similarity to alternative terms that have already been used in the economics

[17]We aggregated across like terms in Table 6 in different combinations and found similar results. VICS remained the dominant term in all cases when included, regardless of how other terms were combined. "Value of decreased mortality risk" became the dominant term when terms with "value" or "WTP" and "mortality," "risk," and "reduce/reduction/reduced" were combined. Results are available from the authors upon request.

literature as a substitute for the "value of statistical life" (e.g., "value of risk reduction," Scotton and Taylor, 2011).

V. Conclusions

In this paper, we describe evidence we gathered through focus groups and a formal ranking exercise to gauge the preferences and acceptance of many alternative terms for communicating the concept of trading off money and small reductions in mortality risks – alternatives to the "Value of Statistical Life." Many individuals in our sample accepted the term "value," but balked at "statistical" and "life." Overall, participants expressed a preference for replacing "statistical" with "risk" or "chance and "life" with "mortality" or "survival." Many also preferred to see directionality in the risk, as in "reducing risk of mortality" or "increasing the chance of survival"—an idea previously endorsed by the EPA's Science Advisory Board (US EPA 2011).

The highest ranked terms were "value of improved chance of survival" and the "value of reduced mortality risk." Although the former led in our formal ranking exercise, the latter has more favorable properties based on our qualitative synthesis of three public focus groups and because the phrase "improved chance of survival" is used by professionals in other settings to refer to distinct concepts. Accordingly, we conclude that the "value of reduced mortality risk" is likely to be the most effective and readily understood alternative to the "value of statistical life" of the many terms we examined.

Of course, our conclusions should be qualified by the limitations of our analysis. First, our focus groups included a small number of subjects – some picked randomly from the DC area and others selected from a convenience sample of non-economists working at the EPA; neither should necessarily be considered representative of the broader public across the US. Second, we did not test all combinations of the building block words, so some alternatives remain untested. Third, although we used reactions of subjects to sample texts embedding the VSL term and concept, we have not formally surveyed a representative sample and swapped the VSL term with our candidate replacement terms (or other terms) to gauge understanding and acceptance. Further, it would be informative to elicit responses from journalists who cover related topics or government communications professionals who interact directly and regularly with the media about how they view alternative terms. If they can understand and accept a replacement term, that would go a long way to gaining the same response by the public.

Thomas Schelling could not have anticipated how often the public and the press misunderstand and misconstrue the term he coined 50 years ago—The Value of Statistical Life. Ultimately, for the betterment of economic literacy, it will be up to academic and government professionals to replace the VSL term in their publications and public speaking with a generally accepted alternative. Whether it will be the "value of reduced mortality risk" remains to be seen.

Appendix A
Focus Groups 1-3 Handout

This is an edited version of an original article that appeared in June 18, 2013, on page A1 in the U.S. edition of The Wall Street Journal.

Rail Safety and the Value of a Life

by Ted Mann

Next month, a major bridge over the Schuylkill River just outside Philadelphia will be declared too unsafe for trains to use. Its wood ties are rotten and officials fear the rails, expanding in the summer sun, will pull the trestle apart.

A handful of serious rail crashes—including a 2008 head-on collision that killed 25 people—prompted Congress to require upgraded rail anti-crash technology, called Positive Train Control. PTC is designed to automatically stop a train even before it runs a red signal or gets into other dangerous situations.

The Federal Railroad Administration says the upgrades could prevent 52 accidents a year, ranging from nonfatal rail-yard mishaps to deadly train crashes. The FRA puts the cost of upgrades at up to $13 billion for passenger and freight railroads.

On Wednesday the Senate Commerce Committee will hold a hearing on railroad safety, including the progress on installing anti-crash gear.

Central to the debate is the delicate matter of putting a dollar value on saving a life. It is an age-old regulatory predicament—namely, whether or not improvements in public safety are worth their costs or whether they steer money away from addressing more serious threats elsewhere.

Executive orders signed by Presidents since require federal agencies to perform cost-benefit analyses when imposing new rules and mandates. For regulations designed to prevent fatalities, that means calculating the economic benefit of preserving a life.

For this purpose, the federal government has adopted a measurement known as the "value of statistical life," or VSL—roughly speaking, the amount of money Americans are willing to spend for reductions in the risks of death. To estimate the VSL, economists observe the prices consumers pay for safety features such as air bags, and the differences in workers' wages between more and less risky jobs, and deduce from these data how much people value lowering their risks of death.

From there, economists extrapolate the VSL, the economic value of saving a single life. Back in 2009, the Department of Transportation put that number at $6 million; today it is calculated at $9.1 million.

The benefit-cost analyses mandated by all presidents since Ronald Regan are intended to inform difficult choices related to public safety, such as whether government regulators should require railroads to upgrade their anti-crash technologies, by comparing the costs of proposed safety improvements to their benefits. These benefits, in turn, are represented in dollar terms by multiplying the VSL by the number of lives that would be saved each year with the new safety measures in place.

According to a National Transportation Safety Board official, "There's always arguments about, 'The technology is not there,' or, 'The money's not there. But at the end of the day, we have to make a choice between the cost of the upgrades and the safety improvements they offer. We see this over and over again in all modes of transportation."

Appendix B
Focus Group 2 Handout

Accidental drowning is a risk faced by everyone who visits beaches. There are several ways to reduce the risk of drowning, such as teaching swimming skills, wearing a life preserver, and swimming with supervision, in particular when a life guard is present. Life guards can reduce the risk of drowning by providing fast response when someone is at risk of drowning.

We would like to reduce the risk of drowning in a popular beach community. One way to reduce the risk is to hire additional life guards to patrol the beach. Hiring, training, and paying wages to additional life guards for the beach **costs money**, including installing additional life guard stands, and providing the life guards with equipment, like flotation devices.

But, we also know that having more life guards reduces the risk of dying from drowning and therefore has some **benefit**. The life guards cannot guarantee they will completely eliminate drownings. Accidents may still occur. For example, an expert swimmer could swallow water and get a cramp and drown before a life guard will reach them. But, having additional life guards will reduce the risk of drownings by providing more eyes on the water to respond quickly in case of danger.

We want to know how much people value the additional lifeguards so that we can compare it to the cost of adding guards to the beach. We do a study and determine that on average people are willing to pay $10 as a beach access fee for an additional life guard at their beach.

Suppose we estimate that the additional lifeguards will reduce the risk of drowning each year from 5 in 100,000 to 4 in 100,000 at this beach, a 1 in 100,000 reduction in the risk of death from drowning.

If 100,000 people visit the beach each year, then on average there will be 1 fewer drowning among the population. We don't know who will be affected, but we know the beach will be safer with the presence of additional lifeguards.

We want to know how much people value the risk of death by drowning by 1 in 100,000 – the result of the program to hire more lifeguards. Say we do a study and determine that on average people are willing to pay a beach access fee of $8 if they are told there would be additional lifeguards hired with that money, and that it would reduce the risk of drowning death by 1 in 100,000.

If each of the 100,000 visitors is willing to pay $8 towards additional lifeguards, then this group of 100,000 people is willing to pay in total $800,000 per year [because 100,000 people x $8 per person per year = $800,000] to reduce the expected number of deaths due to drowning among them by 1 per year. This is sometimes referred to as "saving one statistical life" per year. So in this case the "value of statistical life" would be $800,000.

How much one person is willing to pay, on average, to reduce his or her chance of death by 1 in 100,000 (A)	**Number of people to consider who are at risk of dying from drowning** (B)	**Value of statistical life (VSL)** = (A) X (B)
$8	100,000	$800,000

This is referred to the "value of a statistical life" (VSL), even though what people are valuing is a small change in the chance of dying, or the risk of dying. The VSL is calculated by summing these small values over a large number of people who share the same risks.
We are now able to compare the benefit of hiring additional life guards to the costs of hiring and training them.

Appendix C:
Summary of Ranked Data Analysis

Our objective in analyzing the focus group participants' ranking data was to identify a single candidate term (if one exists) that is unambiguously preferred by the group in the sense that it could defeat all alternatives in a head-to-head vote. This is the so-called "Condorcet winner" and is always the same regardless of the voting system used. That is, the Condorcet winner, if it exists, is robust to any intentional or un-intentional vagaries of the order in which a series of majority-winner votes among the candidates might be arranged. If a Condorcet winner does not exist, then we would like to identify the set of two or more candidate terms that cannot be defeated by all other candidates. (For more details on the logic of the approach, see Stahl and Johnson 2017 Section 3.6.)

To analyze the ranked data, we first combined the rankings of all candidate terms by all 36 participants of Focus Groups 4-7 into a single dataset. Next, we conducted a round-robin tournament by simulating a series of head-to-head votes among all $(17^2\text{-}17)/2$ =136 possible combinations of pairs of terms. Term i defeats term j if i appears strictly higher than j in more of the focus group participants' rankings than does j appear strictly higher than i; participants who were indifferent between i and j were ignored in the head-to-head vote. The results of this step were summarized in a 17 x 17 matrix $\boldsymbol{R}$ in which element $R_{i,j} = 1$ and element $R_{j,i} = 0$ if candidate i defeats j and element $R_{i,j} = R_{j,i} = 0$ in the cases of ties. Figure 1 provides an example to illustrate how $\boldsymbol{R}$ would be constructed from a set of voter rankings of all terms.[18]

Next we used the matrix $\boldsymbol{R}$ to identify the dominant set of terms. Each of the terms in the dominant set defeat each of the terms not in the dominant set in a head-to-head vote, while the dominant set itself may contain a voting cycle (Stahl and Johnson 2017). The dominant set of terms in the example of Figure 1 is u, x, and y. The reader can confirm this result by inspection of $\boldsymbol{R}$: u, x, and y each defeat v, w, and z, but u does not defeat x or y, x does not defeat u or y, and y does not defeat u or x.

We identified the dominant set of candidate VSL replacement terms based on the rankings elicited from the focus group participants using an iterative procedure that checked each possible dominant set in ascending order of sizes, from k = 1 to K, where K=16. For each possible size of the dominant set we constructed all K-choose-k trial sets. In the example in Figure 1 there are 5 possible trial sets: e.g., u compared to v, w, x, y, and z is one trial set; u compared to v,w, then v,x, then v,y, etc. is a second trial set, For each of these trial sets, we used $\boldsymbol{R}$ to determine if each member of the trial set would defeat each member of the complement set in a head-to-head vote by checking whether the corresponding element of $\boldsymbol{R}$ is equal to 1. Because the dominant set is unique, the algorithm can stop as soon as this iterative procedure ascending from k = 1 to K identifies a dominant set. The code used to analyze the ranking data is included in Appendix D.

[18] In this illustrative example we ignore the indifference line (i.e., none of the rankings are less than 0).

To examine the robustness of our results, we used a bootstrap approach (Efron 1979) to estimate the frequency that each candidate term would appear in the dominant set in repeated studies with the same sample size of focus group participants. The basic intuition behind the bootstrap approach is that it uses the empirical distribution of the sample data as a surrogate for the true population distribution of interest (Efron 1999). That is, if our sample of focus group participants is representative of the larger population of potential focus group participants, then the empirical distribution of rankings in our sample can be used as a surrogate for the distribution of rankings in the larger population. Following the bootstrap logic, we calculated the dominant set frequency estimates by finding the dominant set of candidate terms for 10,000 bootstrap datasets using the algorithm described above. Each bootstrap dataset was constructed by taking N = 36 random draws of focus group participant rankings with replacement from the original dataset. The number of times each term appeared in the dominant set among the bootstrap datasets, divided by the number of bootstrap datasets, formed our estimate of the sampling distribution of dominant set membership for each candidate term.

Voter rankings

	1	***2***	***3***	***4***	***5***
u	4	4	5	5	5
v	3	1	2	1	3
w	2	2	3	2	2
x	5	6	4	4	5
y	6	5	4	4	5
z	1	3	1	3	1

→

Number of votes for i over j

	u	***v***	***w***	***x***	***y***	***z***
u	0	5	5	2	2	5
v	0	0	2	0	0	3
w	0	3	0	0	0	3
x	2	5	5	0	1	5
y	2	5	5	1	0	5
z	0	2	2	0	0	0

→

R

	u	***v***	***w***	***x***	***y***	***z***
u	0	1	1	0	0	1
v	0	0	0	0	0	1
w	0	1	0	0	0	1
w	0	1	1	0	0	1
y	0	1	1	0	0	1
z	0	0	0	0	0	0

Figure 1. Illustrative example of round-robin tournament based on the rankings by five voters (1 through 5) of six terms (u through z).

Appendix D. R code to identify dominant set of candidates from a set of voter rankings of all candidates.

```
#==============================================================================
# RANKING.R
#==============================================================================

#------------------------------------------------------------------------------
# PRELIMINARIES:
#------------------------------------------------------------------------------
{
  # install.packages('readxl')
  library(readxl)

  setwd("~/WorkActive/VRR focus groups")

  # Create output file:
  date.time <- gsub(" ","_",Sys.time())
  date.time <- gsub("-","_",date.time)
  date.time <- gsub(":","_",date.time)
  filename  <- paste("RANKING_output_",date.time,".out",sep="")
  outfile   <- file.create(filename)

  set.seed(12345) # Set random number generator seed
}

#------------------------------------------------------------------------------
# SUB-FUNCTIONS:
#------------------------------------------------------------------------------
robin.f <- function(data){ # Round robin tournament
  # INPUTS:
  #
  # OUTPUTS:
  #
  K <- length(data[,1])  # Number of rows in data matrix (candidates)
  N <- length(data[1,])  # Number of columns in data matrix (voters)
  robin <- matrix(0,K,K) # Initialize K x K matrix to hold results of all pair-
                         # wise votes
  for (k in 1:K){ # Rows of robin matrix
    for (q in 1:K){ # Columns of robin matrix
      k.votes <- 0 # number of votes for candidate k over candidate q
      q.votes <- 0 # number of votes for candidate q over candidate k
      for (n in 1:N){
        if (data[k,n]>data[q,n]){
          k.votes <- k.votes + 1
        }
        if (data[q,n]>data[k,n]){
          q.votes <- q.votes + 1
        }
      }
      if (k.votes > q.votes){robin[k,q] <- 1}
      if (q.votes > k.votes){robin[q,k] <- 1}
    }
  }
  return(robin)
}

dominant.f <- function(robin){
  # https://en.wikipedia.org/wiki/Smith_set
  # Each member of the dominant set (aka Smith set or top cycle) defeats
  # every other candidate outside the set in a pairwise election.
  for (k in 1:K){ # For each possible size of the dominant set...
```

```
    trial.sets <- combn(K,k)    # construct all possible trial dominant sets
    M <- length(trial.sets[1,]) # M is the number of trial sets of size k

    for(m in 1:M){ # for each trial dominant set of size k

      # Compare each candidate in trial set with each candidate out of
      # trial set
      in.set  <- trial.sets[,m] # candidates in trial dominant set
      out.set <- setdiff(1:K,in.set) # candidates out of trial dominant set

      dominant <- 1 # initialize dominant to true

      for(candidate1 in in.set){ # for each candidate in trial dominant set
        for(candidate2 in out.set){ # for each candidate out of trial dominant set

          # if candidate in trial dominant set fails to defeat candidate not in
          # trial dominant set, set dominant to false
          if (robin[candidate1,candidate2]==0){
            dominant <- 0
          }
          # if even one candidate in trial dominant set fails to defeat
          # even one candidate not in trial dominant set, then trial
          # dominant set cannot be the true dominant set, so exit both inner
          # loops
          if(dominant==0){break}
        }
        if(dominant==0){break}
      }

      # if all candidates in trial dominant set defeat all candidates not in
      # trial dominant set, then exit m and k loops (since true dominant set
      # will be unique)
      if(dominant==1){break}
    }

    # define dominant.set equal to trial dominant set on exit of m loop
    dominant.set <- in.set

    if(dominant==1){break}
  }

  return(dominant.set)

}

#------------------------------------------------------------------------------
# MAIN PROGRAM:
#------------------------------------------------------------------------------

# SIMULATE DATA (FOR TESTING):
{
  N <- 5
  K <- 7
  data <- matrix(0,K,N)
  for (n in 1:N){
    for (k in 1:K){
      data[k,n] <- ceiling(runif(1)*K)
    }
  }
  data[which(data==0)] <- K+1
}
```

```
# IMPORT DATA FROM EXCEL FILE:
{
  # Initial 17 terms FG4-7:
  data <- as.matrix(read_excel('FG_ranking_data.xlsx','Original 17 terms','C1:AL18'))

  # Initial 17 terms FG4-7 excluding 'Value of improved chance of survival'
  # data <- data[c(1:8,10:17),]

  # New 12 terms FG7:
  # data <- as.matrix(read_excel('FG_ranking_data.xlsx','New 12 terms','C1:H13'))

  # Test terms 1 (based on Stahl and Johnson 2007 Fig 3.3):
  # data <- as.matrix(read_excel('FG_ranking_data.xlsx','Test data 1','C2:G8'))

  # Test terms 2 (randomly generated):
  # data <- as.matrix(read_excel('FG_ranking_data.xlsx','Test data 2','C2:G8'))

  N <- length(data[1,])
  K <- length(data[,1])
}

# ROUND ROBIN TOURNAMENT:
robin <- robin.f(data)

# FIND DOMINANT SET:
dominant.set <- dominant.f(robin)

# BOOTSTRAP SAMPLING DISTRIBUTION OF DOMINANT SET:
{
  Z <- 10000
  dominant.setBS <- matrix(0,Z,K)
  cat('Bootstrap reps:\n',sep='',file=filename,append=T)
  start.time <- proc.time()
  for (z in 1:Z){
      dataz <- data[,sample(1:N,N,replace=T)]
      robinz <- robin.f(dataz)
      dominant.setz <- dominant.f(robinz)
      dominant.setBS[z,dominant.setz] <- 1

      # Print boostrap result to output file:
      cat(sprintf('%6.0f',z),sep='',file=filename,append=T)
      for(k in 1:K){
        cat(sprintf('%3.0f',dominant.setBS[z,k]),sep='',file=filename,append=T)
      }
      cat('\n',sep='',file=filename,append=T)

      if(floor(z/100)==z/100){
        now.time <- proc.time()
        cat('\rCompleted rep ',
            sprintf('%-.0f',z),
            ' of ',
            sprintf('%-.0f ',Z),
            '[ Time remaining = ',
            sprintf('%5.1f',(now.time[3]-start.time[3])/z*(Z-z)/60),
            ' minutes. ]',sep='')
      }

  }
  freq <- colMeans(dominant.setBS)
  dominant.set.size <- rowSums(dominant.setBS)
}

# PRINT SUMMARY RESULTS TO SCREEN:
```

```
print(dominant.set)
print(freq)

# PRINT SUMMARY RESULTS TO OUTPUT FILE:
{
  cat('\n\nDominant set:\n',sep='',file=filename,append=T)
  for(i in 1:length(dominant.set)){
    cat(sprintf('%3.0f',dominant.set[i]),sep='',file=filename,append=T)
  }
  cat('\n\n',sep='',file=filename,append=T)

  cat('Frequency that each term appears in dominant
set:\n',sep='',file=filename,append=T)
  for(k in 1:K){
    cat(sprintf('%2.0f ',k),sep='',file=filename,append=T)
    cat(sprintf('%7.4f\n',freq[k]),sep='',file=filename,append=T)
  }
  cat('\n\n',sep='',file=filename,append=T)

  set.sizeBS <- rowSums(dominant.setBS)
  cat('Frequency distribution of size of dominant set:\n',sep='',file=filename,append=T)
  for(i in 1:max(set.sizeBS)){
    cat(sprintf('%3.0f ',i),sep='',file=filename,append=T)
    cat(sprintf('%7.4f\n',sum(1*(set.sizeBS==i))/Z),sep='',file=filename,append=T)
  }
  cat('\n\n',sep='',file=filename,append=T)

}
```

References:

Aramburo, A. , J Todd, EC George, S Kiguli, P Olupot-Olupot, RO Opoka, C Engoru, SO Akech, R Nyeko, G Mtove, DM Gibb, AG Babiker, and K Maitland. 2018. “Lactate Clearance as a Prognostic Marker of Mortality in Severly Ill Febrile Children in East Africa,” *BMC Medicine* 16:37.

Banzhaf, Spencer. 2014. Retrospectives: The Cold-War Origins of the Value of Statistical Life. *Journal of Economic Perspectives.* 28(4): 213-226.

Cameron, Trudy. 2010. Euthanizing the Value of a Statistical Life. *Review of Environmental Economics and Policy*. 4(2):161-178.

Davis, BL, MJ Martin, M Schrieber. 2017. “Military Resuscitation: Lessons from Recent Battlefield Experience.” *Current Trauma Reports*. 3(2):156-163.

Efron, B. 1979. Bootstrap Methods: Another Look at the Jacknife. *Annals of Statistics.* 7(1): 1-26.

Efron. B. 1999. *The Bootstrap and Modern Statistics*. Technical Report #206. Stanford University, Division of Biostatistics: Stanford, CA. August.

Fukuda T, N Ohashi-Fukuda, H Kobayashi, M Gunshin, T Sera, Y Kondo, and N Yahagi. 2016. “Conventional versus Compression-only versus No Bystander Cardiopulmonary Resuscitation for Pediatric Out-of-hospital cardiac arrest.” *Circulation.* 134(25):2060-2070.

Furrow. B. 2016. Medical Malpractice Liability. In *Oxford Handbook of U.S. Health Law*, edited by I Glenn Cohen, Allison Hoffman, and William M. Sage, 421-443. Oxford University Press.

NRDC 2003. “Cheapening the Value Of Life: The Bush Administration's Death Discount April 1, 2003. Available at: https://www.nrdc.org/media/2003/030401-0.

Robinson, Lisa A. 2007. "How US Government Agencies Value Mortality Risk Reductions." *Review of Environmental Economics and Policy* 1(2): 283-299.

Schelling, Thomas C. 1968. The Life You Save May Be Your Own. In *Problems in Public Expenditure Analysis*, edited by Samuel B. Chase, Jr., 127–62. Washington, DC: Brookings Institution.

Scotton, Elizabeth, and Laura Taylor. 2011. Valuing risk reductions: Incorporating risk heterogeneity into a revealed preference framework. *Resource and Energy Economics.* 3(2): 381-397.

USEPA. 2010a. *Guidelines for Preparing Economic Analyses.* Office of the Administrator, Office of Policy. EPA 240-R-10-001. December. R-10-001. December. Available at: http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/ Guidelines.html.

USEPA. 2010b. Valuing Mortality Risk Reductions for Environmental Policy: A White Paper. SAB Review Draft. Office of Policy, National Center for Environmental Economics. December 10. Available at: http://yosemite.epa.gov/sab/sabproduct.nsf/c91996cd39a82f6485257424 00690127/34D7008FAD7FA8AD8525750400712AEB/$File/White+Paper+(Dec.+2 010).pdf.

USEPA. 2011. Review of Valuing Mortality Risk Reductions for Environmental Policy: A White Paper (December 10, 2010). Office of the Administrator, Science Advisory Board. EPA-SAB-11-011. July 29. Available at: http://yosemite.epa.gov/sab/sabproduct.nsf/298E1F50F844BC23852578DC0059A 616/$File/EPA-SAB-11-011-unsigned.pdf.

USEPA. 2016. Economic Analysis of the Formaldehyde Standards for the Composite Wood Products Act Final Rule. July 2016. Available at: https://www.regulations.gov/document?D=EPA-HQ-OPPT-2016-0461-0037.

USEPA. 2017. SAB Review of EPA's Proposed Methodology for Updating Mortality Risk Valuation Estimates for Policy Analysis. January 2017. Available at: https://yosemite.epa.gov/sab/sabproduct.nsf/436C15984A487E1F852580D00044 29CF/$File/EPA-SAB+2017-005+Unsigned.pdf.