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Mortality beliefs distorted: Magnifying the risk of dying young

ESMT Working Paper, No. 13-03

Provided in Cooperation with:
ESMT European School of Management and Technology, Berlin

Suggested Citation: Jarnebrant, Peter; Myrseth, Kristian Ove R. (2013) : Mortality beliefs distorted: Magnifying the risk of dying young, ESMT Working Paper, No. 13-03, European School of Management and Technology (ESMT), Berlin, https://nbn-resolving.de/urn:nbn:de:101:1-201303269090

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13-03

February 27, 2013

ESMT Working Paper

MORTALITY BELIEFS DISTORTED

MAGNIFYING THE RISK OF DYING YOUNG

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ISSN 1866-3494

ESMT European School of Management and Technology

Abstract

Mortality beliefs distorted: Magnifying the risk of dying young[+]

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We explore mortality beliefs by eliciting individual-level belief distributions for participants' remaining lifespan. Across two independent samples, from Germany and the USA, we find that individuals—while accurately forecasting their life expectancy—substantially overestimate the likelihood of dying young (<50 years) and overestimate the likelihood of reaching very old age (>100 years). In other words, the modes of the belief distributions are relatively accurate, but the tails of the belief distributions are significantly 'fatter' than the corresponding tails of distributions obtained from demographic data. Our results are robust to variations in belief elicitation techniques, and to assumptions underlying normative longevity forecasts. The results have implications for a range of questions of economic behavior—including intertemporal choice, consumption smoothing, saving, and risk management.

Keywords: mortality, beliefs, risk perception, judgment

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+ We thank Isaac Dinner, Paul Heidhues, Dan Goldstein, Catalina Stefanescu-Cuntze, Olivier Toubia, Joachim Vosgerau, and Conny Wollbrant for thoughtful comments and helpful suggestions. Claudia Scheurig provided research assistance.

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Mortality Beliefs Distorted:

Magnifying the Risk of Dying Young

Though mortality stands as one of life's few certainties, our expiration date does not. And while at some level terrifying, an understanding of our expected lifespan is essential. Knowing the onset of death allows the rational planner to allocate her consumption over time; to manage risky behavior; and to invest accordingly. Indeed, subjective life expectancy predicts: actual life expectancy (Smith, Taylor, & Sloan, 2001); savings and consumption (Salm, 2010); retirement and social security claiming (Hurd, Smith, & Zissimopoulos, 2004); tobacco usage, and regular exercise (Hurd & McGarry, 1995). Such planning, however, will prove difficult if individuals misperceive their mortality. And there are grounds for concern. We find that our respondents substantially underestimate the likelihood that they reach middle age (<50 years), but—paradoxically—overestimate the likelihood that they reach very old age (>100 years). The latter result is consistent with the common—but recently questioned—notion in psychology that individuals wear 'rose-tinted' glasses (Harris & Hahn, 2011), but the former is not.

We also contribute to the literature by eliciting individual-level belief distributions about mortality. To date, subjective mortality expectations have been captured by asking each participant one or two questions, such as "how long do you expect to live?" or "how likely is it that you reach the age of 75?" (e.g., Elder, 2012; Hamermesh, 1985; Hamermesh & Hamermesh, 1983; Hurd & McGarry, 1995; Hurd & McGarry, 2002; Mirowsky, 1999; for a general review about the measurement of expectations, see Manski, 2004). In contrast, we obtain subjective mortality forecasts for individuals' entire remaining lifespans. This allows us to compute an aggregated 'subjective curve of death.' The curve is important because, relative to a point estimate, it offers a richer picture of our subjective life horizon. It reveals not only central

tendencies of expected longevity (e.g., mean and median of the elicited distribution), but also the age at which we think we are most likely to die (i.e. the mode), our perceived likelihood of dying young and of reaching very old age. Further, the curve permits a detailed comparison against actuarial forecasts of mortality. We assess whether individuals systematically misperceive their lifespan, and if so, for which ages their expectations are better calibrated.

We present the results of two studies. Study 1 features German students in a laboratory, Study 2 U.S. survey-takers online. Both samples yield similar belief distributions and similar patterns of deviation from actuarial forecasts. In line with the literature, participants' implied expected longevity is fairly well-calibrated. However, there is substantial miscalibration of the tails of the belief distributions. Notably, (young) participants seem to substantially overestimate the risk of dying young—but overestimate the likelihood of reaching very old age. Put differently, the tails of the subjective belief distributions are much fatter than the corresponding tails of the actuarial mortality distributions. The exaggerated subjective mortality for young ages was stronger for U.S. than for German participants—while for extremely old ages it was greater for German than for U.S. participants. The results hold up against conservative actuarial standards, and they prove robust to variations in the procedure for eliciting mortality expectations.

Our results accommodate prior findings in the literature (e.g., Hurd & McGarry, 1995, 2002), which show that older individuals somewhat underestimate the likelihood of reaching age 75 and somewhat overestimate their likelihood of reaching age 85. However, because our studies feature younger individuals, who are asked about earlier ages than are those featured in the aforementioned studies, and because we also ask about more extreme old age, we capture subjective mortality for age ranges not featured in these studies. Accordingly, we report biases in subjective mortality, at either extreme of the distribution, higher by one order of magnitude or

more.

Study 1: German Sample

In a laboratory experiment, we asked 132 participants (mostly German university students) how *plausible* they deemed the possibility of reaching various age ranges.[1] Participants were given nine 10-year intervals, for which they answered this question on a continuous scale, in the form of a slider, ranging from 0 to 100, with endpoints "*Not at all*" and "*Extremely*".[2] We obtained life tables for this demographic group from the Human Mortality Database (2012; HMD), which compiles demographic data on a number of different countries; these life tables serve as the input for our actuarial mortality forecasts, against which we compare individual belief distributions.

Because participants likely held idiosyncratic interpretations of the scales in the elicitation schedules, we standardized their responses to a common scale of probability density. Assuming that the sum of their responses across all ranges could be interpreted as "100 percent,"[3] we divided each of their individual responses by the sum of their nine responses to obtain their standardized probabilities. We conducted all subsequent analyses with the standardized probabilities.

Figure 1 presents the aggregated individual belief distributions, fitted with a Weibull

[1] The sample consisted of 36% females and 64% males; average age was 25.9 years, *SD* = 5.5.
[2] These questions were framed either as a probability density function (e.g., "at least 30, but no more than 40 more years") or a cumulative distribution function (e.g., "at least 40 more years"). Moreover, participants were asked either how *plausible* or how *likely* they deemed the possibility of reaching each of these bins. This yielded a 2×2 factorial design, in which participants were randomly assigned to one of the four conditions. The purpose of the design was to explore the robustness of our elicitation procedure. However, because we failed to discern statistical differences in responses to the different elicitation techniques, we present analyses of data collapses across conditions. Beliefs were elicited with four slightly different techniques, to which participants were randomly assigned. Because we observe no statistical difference across conditions, we report only the collapsed data. For a more detailed discussion of our techniques, and for results broken down by condition, materials and methods are available in the Supplemental Online Material.
[3] Conceptually, this is identical to providing participants with a "probability pie" that they divide up between the various mutually exclusive outcomes.

curve[4] (Weibull, 1951). Notably, the mean subjective life expectancy is 79.8 years, which coincides well with the current mortality in the German population, namely 80.4 years;[5] that subjective life expectancy appears reasonably well-calibrated is consistent with the literature (Mirowsky, 1999).

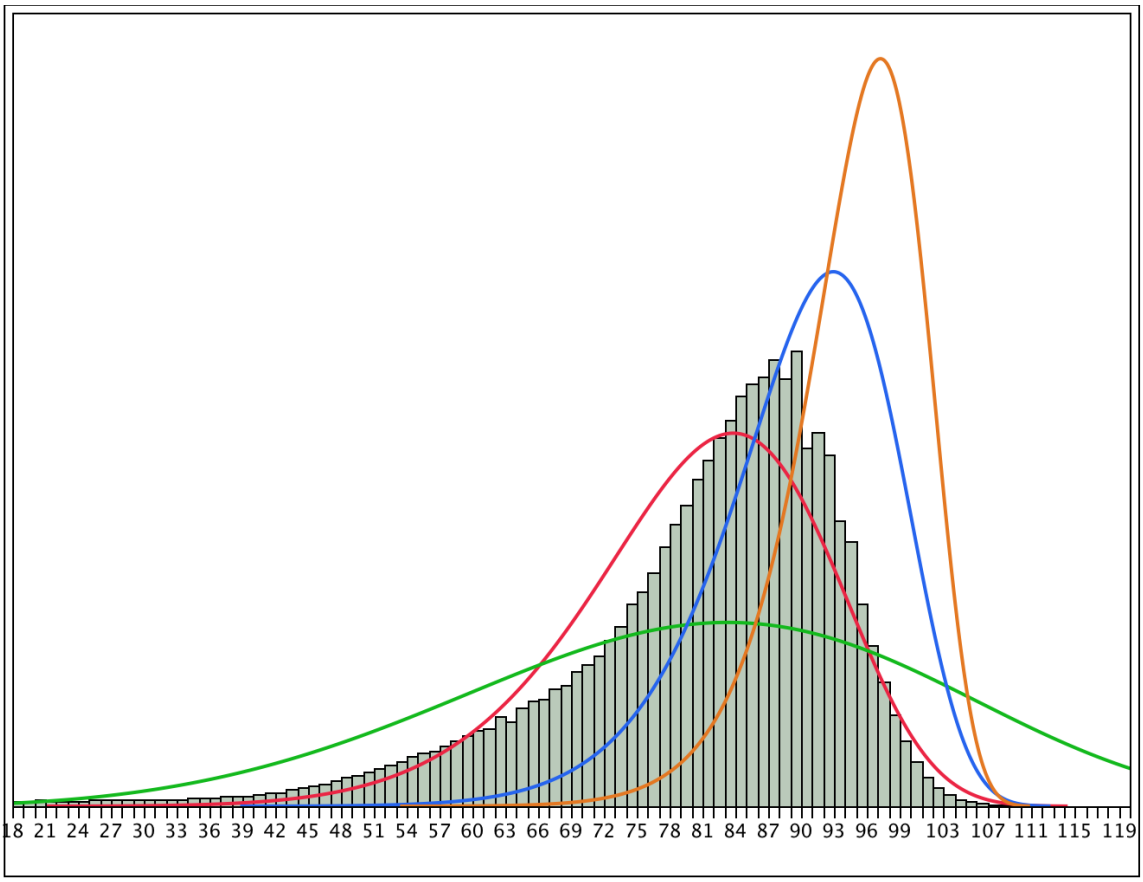

Figure 1. Results of study 1 (U.S. participants). Four Weibull models show: elicited beliefs (green line); 2009 life-table data (red line; green bars show the data); and forecasts for the years 2070 (blue line); and 2132 (yellow line).

[4] We note that the belief distribution for an individual of high age, compared to that of an individual of lower age, necessarily will encompass a smaller portion of the actuarial mortality distribution, across all ages. To aggregate belief distributions across individuals of different ages, we thus applied a correction factor according to the age of each individual. See the Supplemental Online Materials for details on its implementation.

[5] Using the Lee-Carter procedure (Lee & Carter, 1992), forecasted longevity in Germany for 2070 and 2132 are 89.7 and 94.8, respectively.

To compare the belief distributions against actuarial predictions for life expectancy, we also plot in figure 1 the estimated belief distribution (i.e., the Weibull model), obtained above, against the life table data, and against forecasted mortality in 2070 and 2132, respectively—obtained with the Lee-Carter procedure (Lee & Carter, 1992). Because current death rates likely underestimate current life expectancy (Elder, 2012)—life expectancy has been consistently increasing—forecasted mortality provides a more conservative standard of comparison for beliefs about the likelihood or reaching very old age. However, current mortality offers the more conservative standard for beliefs about the likelihood of dying young. In any event, our plots show that the tails of the belief distributions are substantially fatter than those of any of the actuarial predictions; individuals quite significantly overestimate the likelihood that they will die young, and they overestimate grossly the likelihood of reaching very old age (>100 years).

We plot in figure 2 the ratios of German beliefs against current German mortality data; participants overestimate mortality by a factor of about 2, for the age range of approximately 33 to 43. Beliefs reach accurate calibration between ages 68 and 69, but by age 98 beliefs again overestimate probability of death age approximately by a factor of 2. This overestimation then rises steeply, reaching 562.6 at age 109.

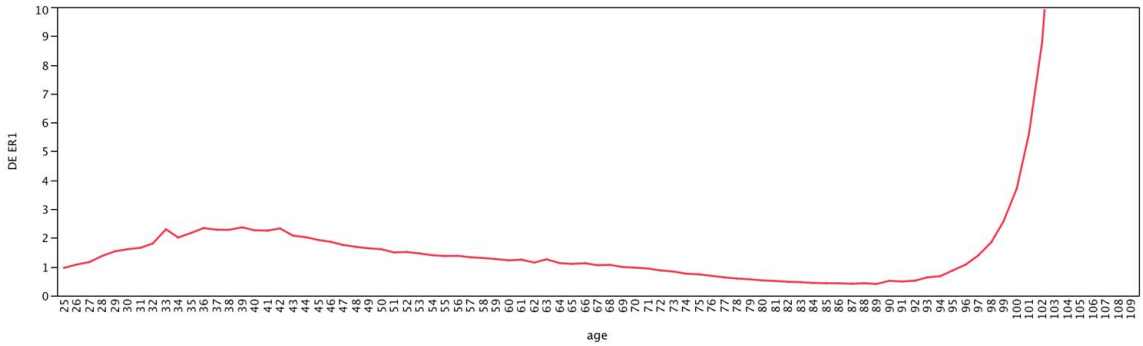

Figure 2. Study 1 error ratios. The line shows the ratio of the Weibull model of beliefs to life-table data.

Study 2: U.S. Sample

The purpose of our second study was to replicate the results from Study 1 in a sample of greater size, different national origin, and of wider demographic composition. Furthermore, responses were obtained via an online panel, as opposed to sessions in the laboratory. We elicited belief distributions by asking participants how plausible they deemed the prospect of reaching, but not exceeding, various age ranges. As such, the empirical procedure in Study 2 resembled that of Study 1.[6]

Participants from the Amazon Mechanical Turk survey panel (495 in total) completed the study online in exchange for payment.[7] We again obtained life tables from the HMD (2012), as input for actuarial forecasts of U.S. mortality.

We applied the same procedures as in Study 1 for standardizing and aggregating beliefs.[8]

In figure 3, we plot the Weibull model of the elicited belief distribution against the distribution of current mortality, and against forecasted mortality in 2070 and 2132, respectively—obtained with the Lee-Carter procedure (Lee & Carter, 1992). The mean subjective life expectancy is 75.3 years, slightly lower than current mean age at death in the U.S. population of 79.0 years.[9] The figure echoes the results from Study 1; the tails of the belief distributions are substantially fatter than those of any of the actuarial predictions; individuals exaggerate substantially the likelihood that they will die young, and the likelihood of reaching very old age (>100 years).

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[6] Strictly speaking, the procedure was an exact replication of one of the four variations utilized in Study 1.See the Supplemental Online Materials for details and justification.

[7] The sample consisted of 55% females and 45% males; average age was 35.1 years, *SD* = 11.5.

[8] Readers might note that the correction factor applied to individual beliefs, for the purpose of aggregating beliefs across respondent ages, is more important in Study 2 than in Study 1; the latter sample has both a higher average age, and a higher variation.

[9] Using the Lee-Carter procedure (Lee & Carter, 1992), forecasted longevity in the US for 2070 and 2132 are 86.1 and 90.7, respectively.

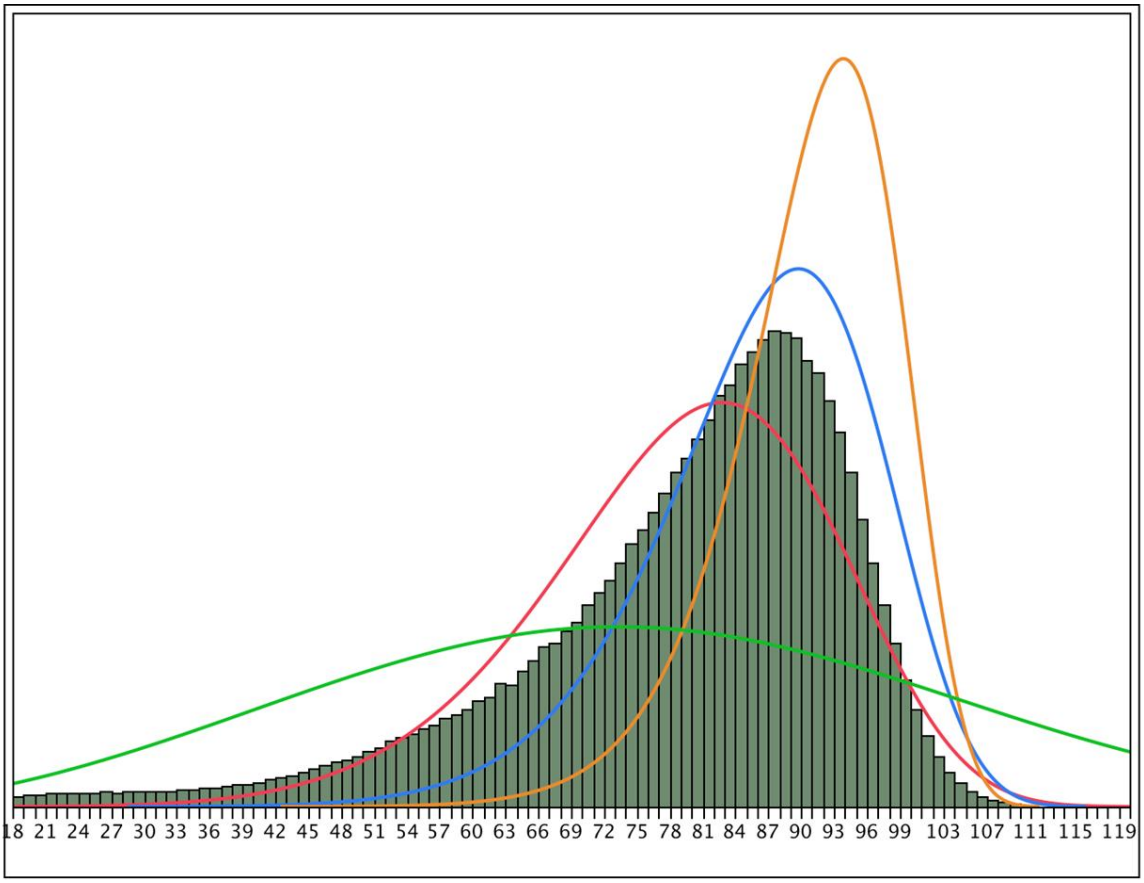

Figure 3. Results of study 2 (U.S. participants). Four Weibull models show: elicited beliefs (green line); 2009 life-table data (red line; green bars show the data); and forecasts for the years 2070 (blue line); and 2132 (yellow line).

Figure 4 plots the error ratios of U.S. beliefs against current U.S. mortality data. Respondents overestimate mortality probabilities by a factor of about 4 for the age range of 30 to 40. Beliefs reach accurate calibration between ages 68 and 69, but by age 101 beliefs overestimate survival approximately by a factor of 2. This overestimation then (as in Study 1) rises sharply, reaching (61.5) at age 109.

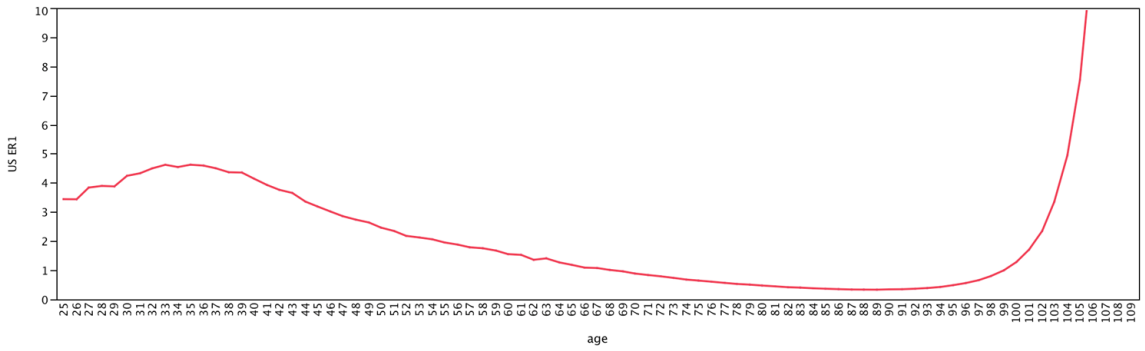

Figure 4. Study 2 error ratios. The line shows the ratio of the Weibull model of beliefs to life-table data.

Gender-specific Analyses

The life table data from the HMD (2012) allows a breakdown by gender. We find that beliefs are not significantly different for males and females; see figure 5 and 6. Both models fit the data (fit cannot be rejected at $p>.25$ by the W test), but neither scale nor shape parameters can be statistically distinguished from each other ($ps>.05$).

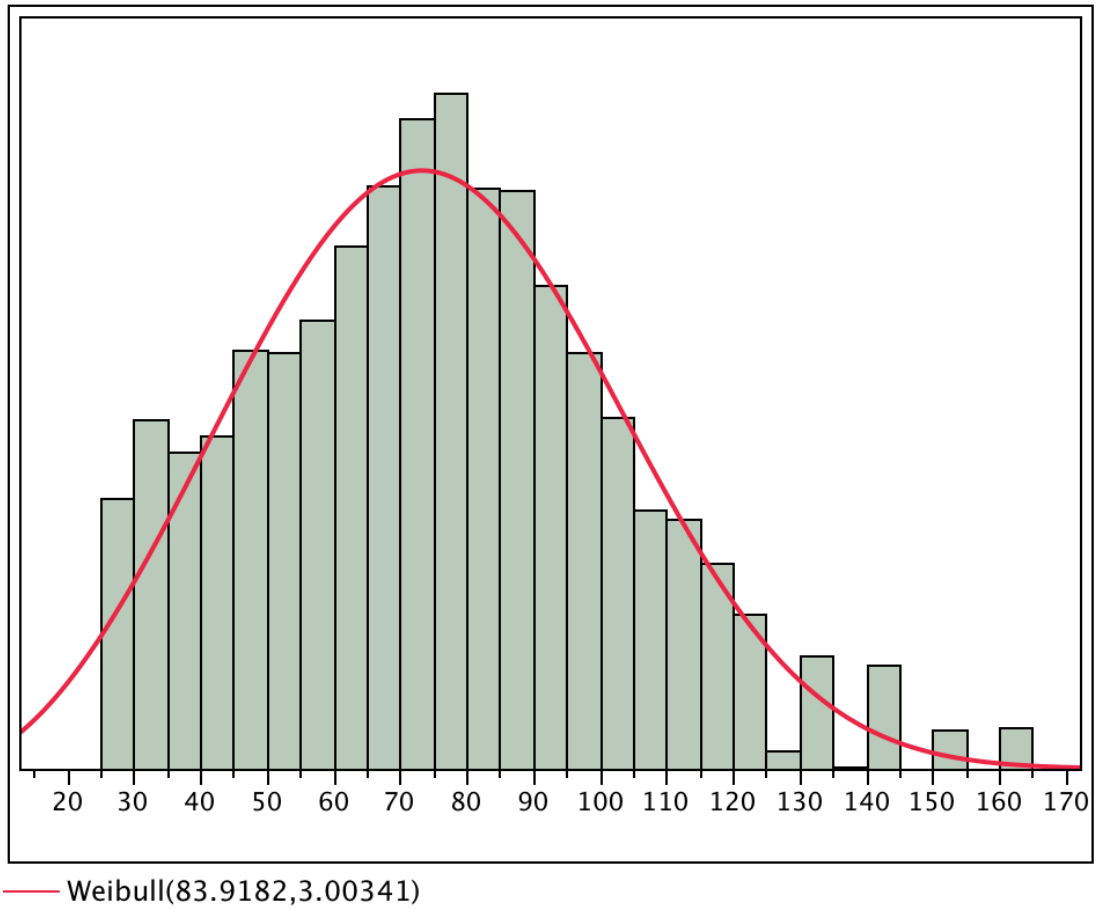

Figure 5. Beliefs of U.S. males with superimposed Weibull curve (numbers in parenthesis indicate scale and shape parameters, respectively).

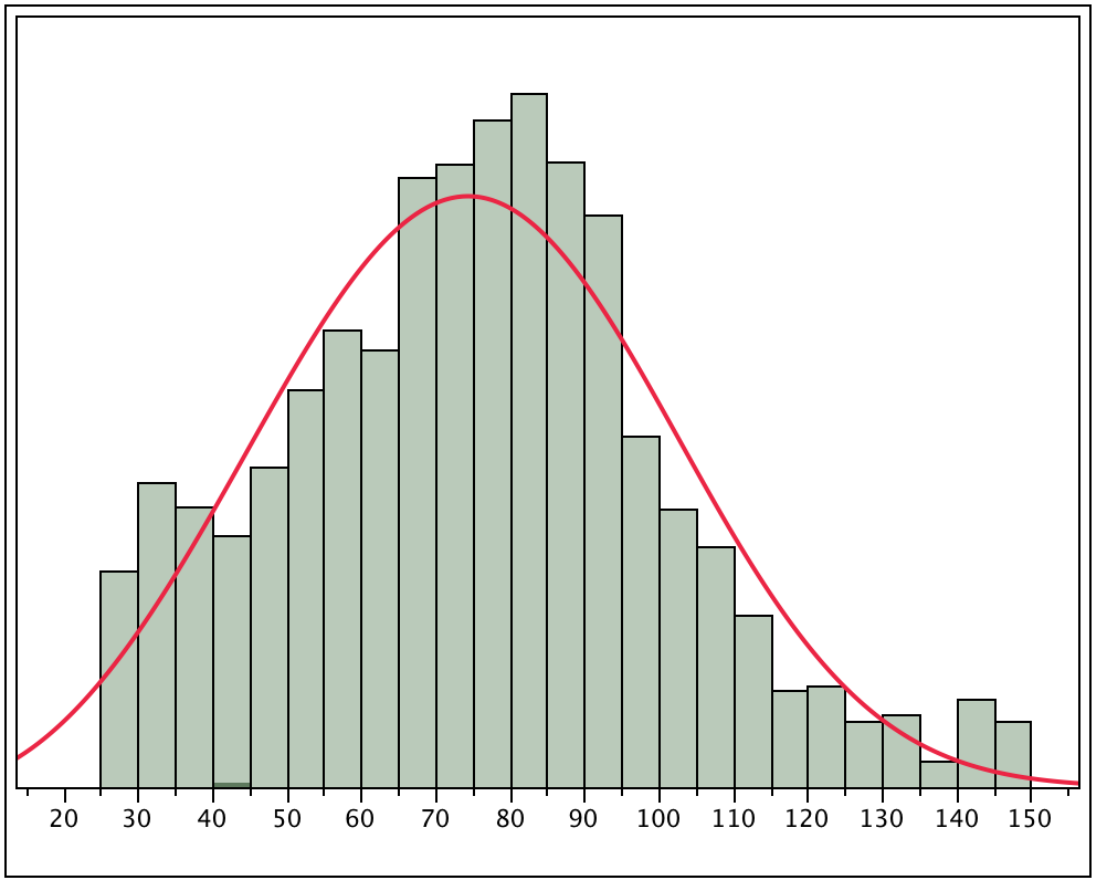

Figure 6. Beliefs of U.S. females with superimposed Weibull curve (numbers in parenthesis indicate scale and shape parameters, respectively).

We next compare how beliefs correspond to gender-specific life table population data, illustrated in figures 7 and 8.

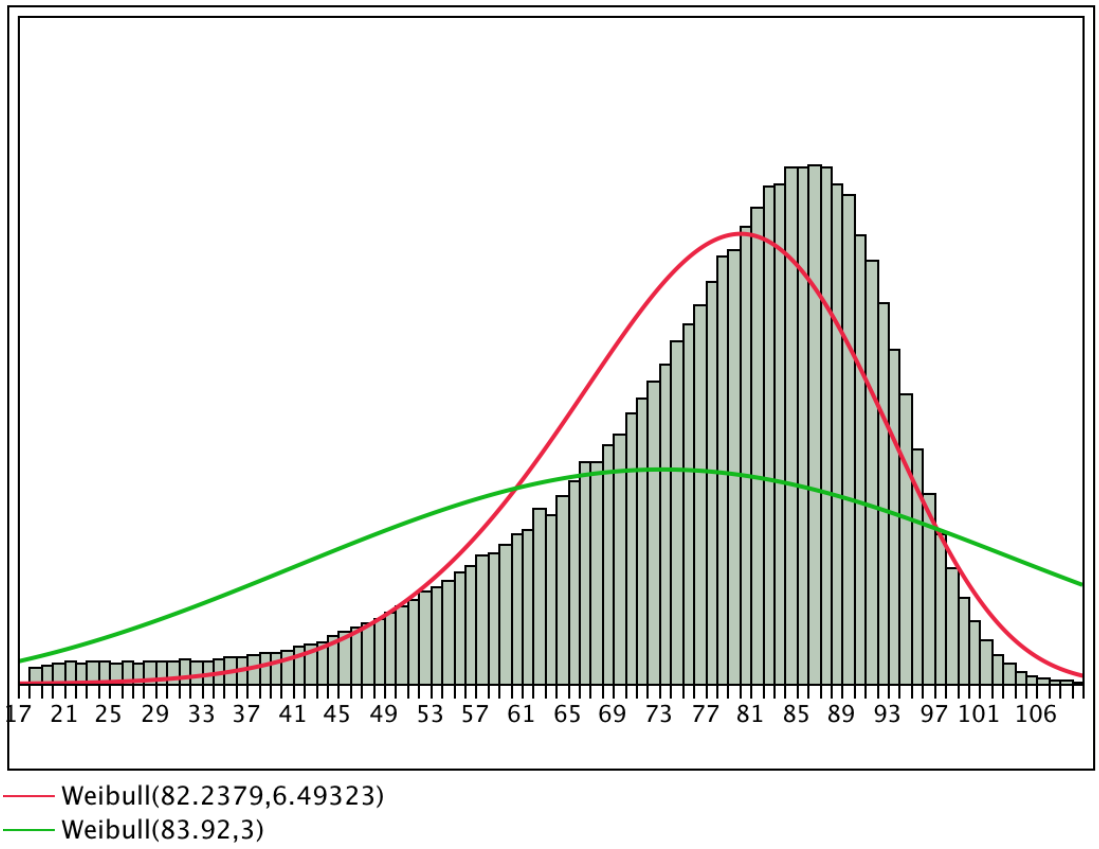

Figure 7. Life table data for U.S. males, with superimposed Weibull curves for the population (red) and the beliefs of U.S. males (green) (numbers in parenthesis indicate scale and shape parameters, respectively).

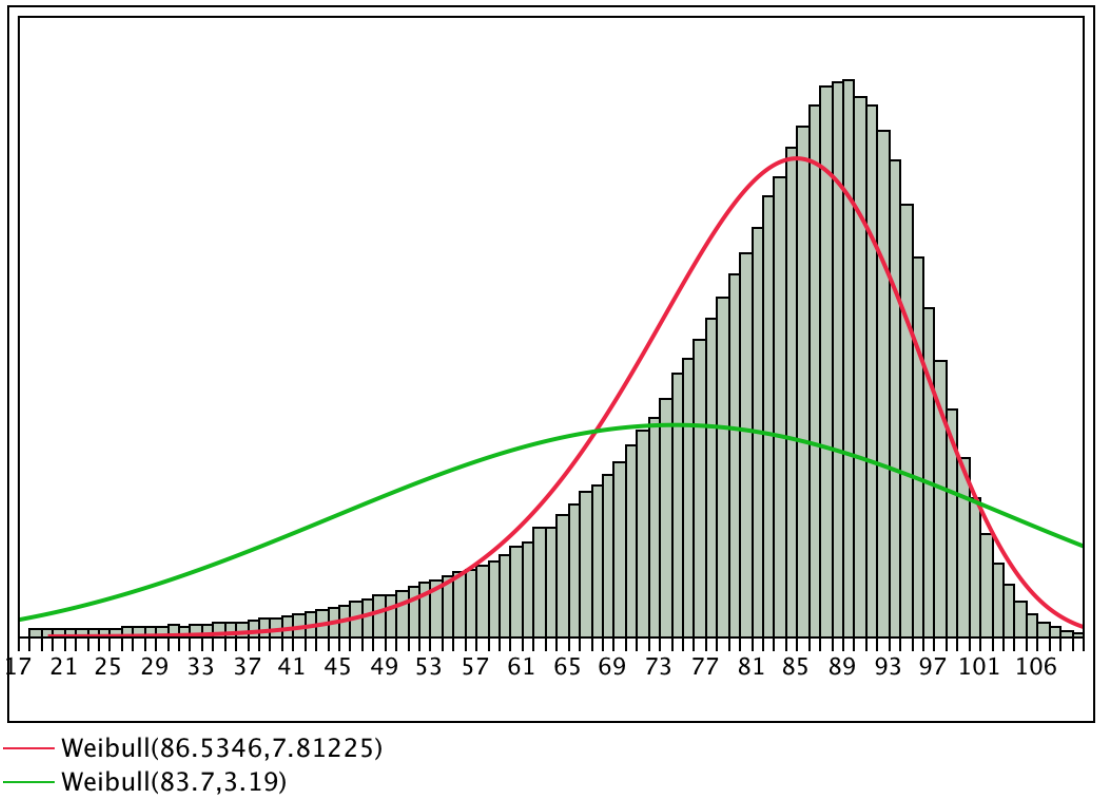

Figure 8. Life table data for U.S. females, with superimposed Weibull curves for the population (red) and the beliefs of U.S. males (green) (numbers in parenthesis indicate scale and shape parameters, respectively).

Producing error ratios from the Weibull models of beliefs and the raw life table data then yields the pattern in figure 9:

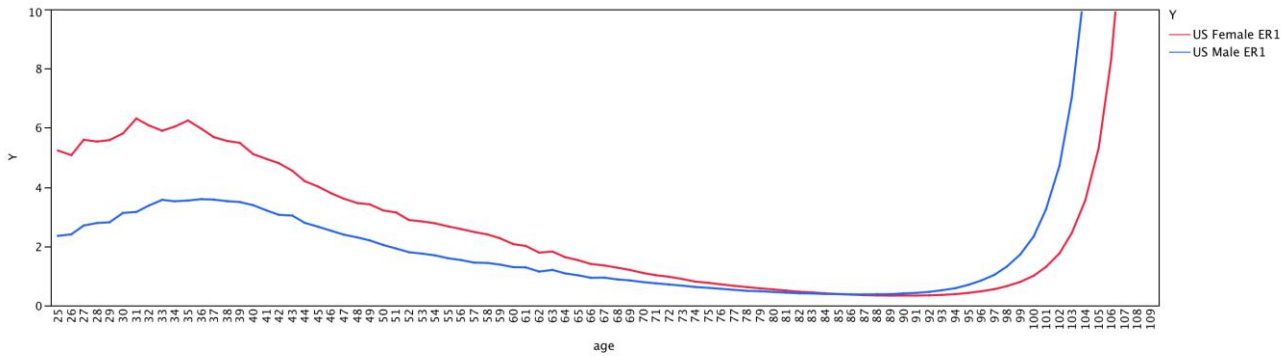

Figure 9. Error ratios of U.S. males (blue) and females (red); in both cases ratios are computed using fitted Weibull models for the belief data and raw life table data for the populations.

It is evident that the pessimism of death during youth is greater for females than for males—but that the optimism about death as a centenarian is greater for males. Notably, however, the general curvilinear pattern that we observed in the aggregate results holds for both genders.

That there is no gender difference in beliefs—despite rather profound differences in the actuarial death distribution, is quite striking and might speak to the psychological mechanism that underlies belief formation. It would, for example, be consistent with an availability account (Tversky & Kahneman, 1973; 1974), whereby individuals form—or report—beliefs by relying on accessibility or fluency of information retrieved from memory (Colin & Campbell, 1992; Schwarz & Vaughn, 2002). Both men and women might imagine the risks of American youth—a car accident or gun violence—but then fail to condition their expectation on their gender. Women would then neglect that young men are overrepresented in fatal accidents and shootouts, and men would forget that women stand a higher chance of reaching very old age.

Discussion

Across two studies, individuals report distorted beliefs about mortality across their lifespan. Although their mean longevity is fairly well-calibrated, the tails of their belief distributions are too fat on either end. In other words, individuals substantially overestimate both the risk of dying young and the chances that they reach very old age.

These results accommodate and extend the literature, which reports relatively accurate subjective longevity estimates (Hurd & McGarry, 1995; 2002), with a slight pessimism bias among older respondents (age >50) about the likelihood of reaching age 75 (believed = .645 vs. actual = .677) and a small optimistic bias about the chance of reaching 85 (believed = .427 vs. actual = .349).[10] We observe pessimism that is of an order of magnitude greater than that previously reported for an adult population. The reason for this, it seems, is that past findings of

[10] From the Health and Retirement Study, wave 1.

pessimism arise from the recurring Health and Retirement Study (HRS), which asks not about mortality at younger ages—where our measured pessimism bias is largest—but instead requests respondents to indicate the likelihood of reaching older ages, namely ages 75 and 85. Other studies, such as (Mirowsky, 1999), focus exclusively on subjective expected longevity, and they find reasonable calibration for this metric, in line with the mean subjective longevity obtained from our belief distributions. Moreover, as Elder (2012) observes, the results from the HRS imply a "flatness bias" in subjective mortality distributions; respondents seem to believe that mortality increases at a constant as opposed to increasing rate. An informal visual inspection of our belief distributions reveals a similar picture.

Finally, our results are consistent with those obtained by Bruine de Bruin, Parker, and Fischhoff (2007), who report that 15-16 year-old adolescents of the 1997 National Longitudinal Study of Youth wildly overstate the likelihood of dying within the next year (18.7 % vs. .1%) and before they reach age 20 (20.3% vs. .5%). Our belief distributions imply that their findings are not mere artifacts of adolescence, but rather represent a more general phenomenon.

As a theoretical concept, mortality beliefs are important. Many big decisions involve the joint consideration of death's certitude—and its uncertain arrival. Should we live for the moment, or invest in the future—consume now or save for retirement? If our mortality beliefs are distorted, it would be hard to get these decisions right.

Both authors contributed equally to all aspects of the study, analysis, and the written report. Authorship order is alphabetical.

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Supplemental Online Material (SOM–R)

In this Supplement, we provide additional details on methodology and data used. It is

structured as follows:

Data and Sources

Models

Methods: Study 1, Study 2

Correction for remaining life expectancy

Forecasts

Error ratios

Comparison to point estimates

References

Data and Sources

As normative comparisons for our elicited mortality beliefs, we rely on actuarial data from the Human Mortality Database (2012, HMD), which houses extensive international mortality data. The HMD originated as a collaborative effort between the Department of Demography at the University of California, Berkeley, USA, and the Max Planck Institute for Demographic Research in Rostock, Germany; it is the source of mortality data for a vast amount of research (see e.g., http://www.mortality.org/Public/HMD-Publist.pdf).

The HMD data for the U.S. is based on statistics collected by the National Center for Health Statistics (2012).

To arrive at a distribution for the total number of deaths occurring in a given country, we use life table data—the most recent available (2009)—in addition to data on the total number of deaths per country.

The raw life table data for Germany and the U.S. can be shown as ‘curves of death,’ which display the probability that an age-0 individual’s death occurs at a given age. Below, in

figures S1 and S2, these curves are given for both countries, over age ranges relevant for our empirical samples. In addition, Weibull distributions have been fitted to the data.

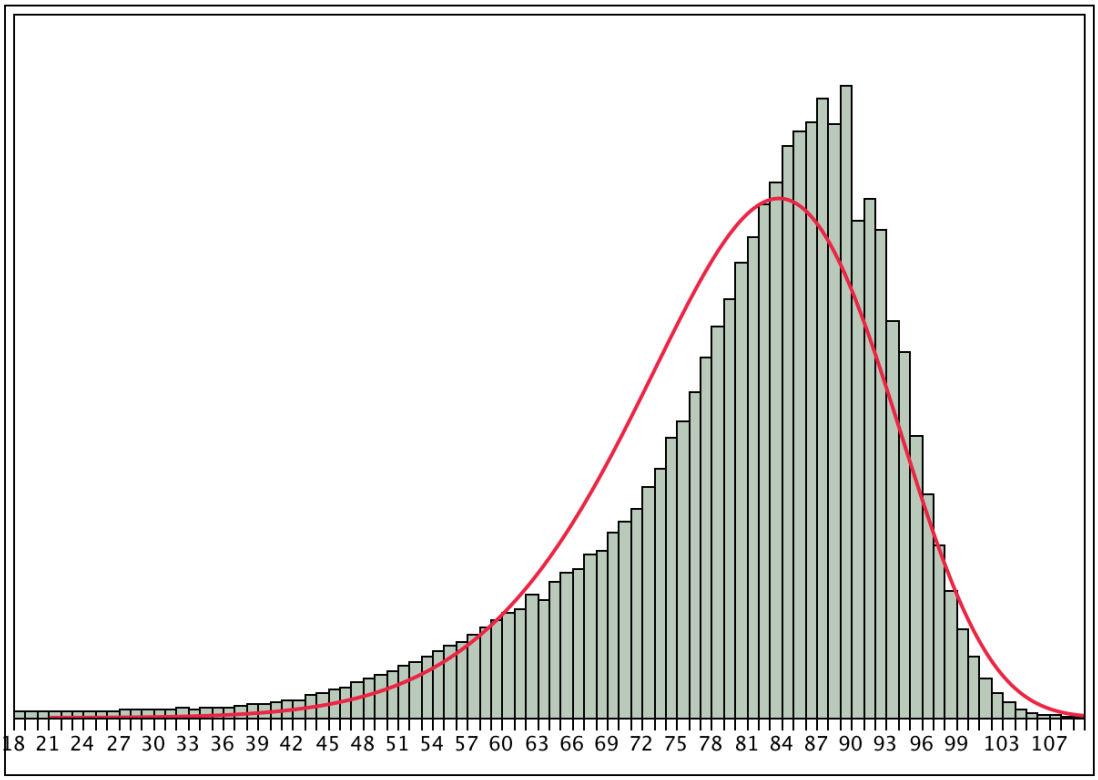


Figure S1. The distribution of deaths in Germany, 2009. The red line indicates the best-fit Weibull distribution (scale 85.13, shape 8.37). *N*=1 698 049.

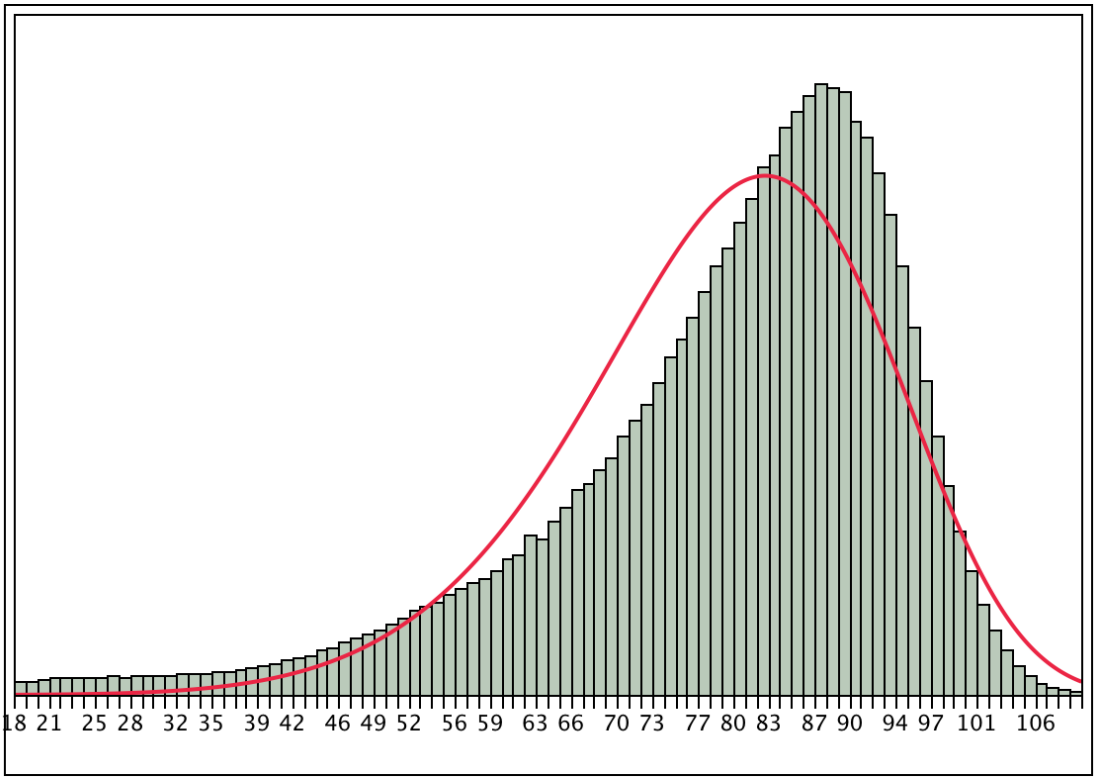


Figure S2. The distribution of deaths in the U.S., 2009. The red line is the best-fit Weibull distribution (scale 84.62, shape 6.97). *N*=2 142 280.

It should be noted that these Weibull distributions are not statistically perfect fits for the data; by Cramer-von Mises *W* tests, the fits are rejected at $p<.0001$. However, comparison to other distributions (e.g., double exponential) has not resulted in better fits. Given the large number of data points, it is perhaps not surprising that the W test rejects the fits. We are providing the fitted distributions for visual illustration, and for comparison to the Weibull distributions that we fit to the belief data from our empirical surveys, which do fit by the same test. In addition, the pattern in future developments of life expectancy produced by our Lee-Carter forecasts can be easily seen by comparing fitted Weibull distributions (see figures 1 and 3 in the main article).

Models

The Weibull distributions that we fit to the survey and life table data were estimated using SAS JMP version 10. Two-parameter models were used, and the quality of fit was measured by Cramer-von Mises *W* tests.

Weibull distributions are frequently used in modeling various survival processes, including human mortality (e.g., Perozek, 2008; Lawless, 1982; Weibull, 1951).

Methods

Study 1.

Procedures.

As this was our first attempt at eliciting belief distributions, we explored four related but slightly different techniques, to which participants were randomly assigned. We asked participants either how *plausible* it was that they would reach various age ranges or how *likely*. These questions were in turn framed either as a probability density function (e.g., "*at least 30, but no more than 40 more years*") or a cumulative distribution function (e.g., "*at least 40 more years*"). We computed participants' actuarial life expectancy against which we compared their subjective beliefs.

We recruited participants from a large technical university in Germany, to the laboratory for a "consumer lifestyle study" in return for cash compensation equivalent to a 10-euro hourly rate. The study lasted about 15 minutes.

Participants were seated in front of computers, counting 17–24 at a time, in 9 sessions. The study was completed with *Qualtrics* survey software.

After the initial landing page, participants were presented with a screen that contained the entire belief elicitation schedule (see figures S3 and S4). Participants were randomly assigned

within sessions to one of four experimental conditions, each reflecting different techniques for eliciting subjective life expectancy: asking about *plausibility* or *likelihood* of survival either by eliciting probability density or a cumulative distribution.

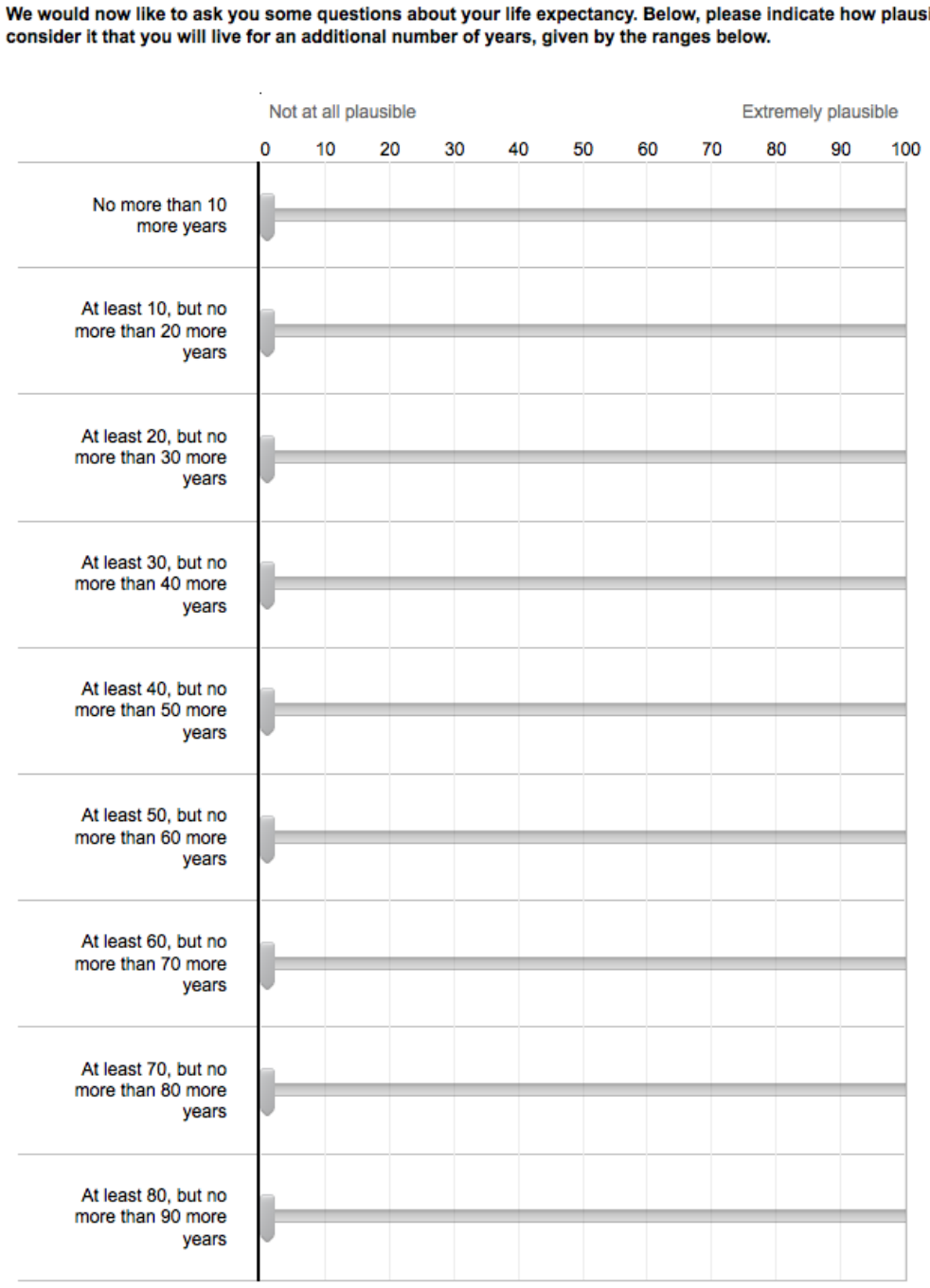


Figure S3. Belief elicitation schedule. Probability density condition using *plausiblity*.

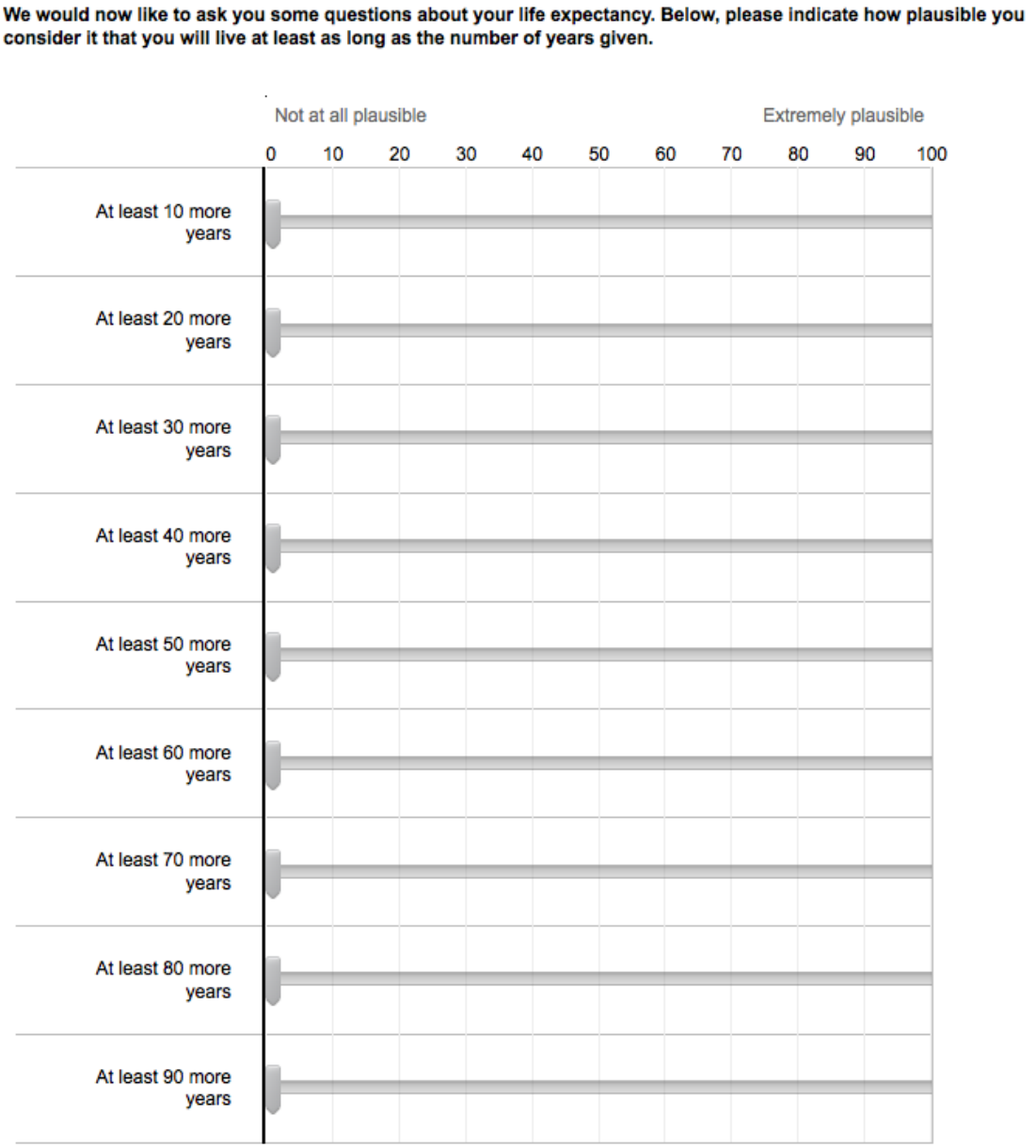


Figure S4. Belief elicitation schedule. Cumulative density condition using *plausiblity*.

For participants in the probability density condition, the belief elicitation schedule was introduced with the following question: "*...indicate how plausible [/likely] you consider it that you will live for an additional number of years, given by the ranges below.*" Participants were given nine 10-year intervals, for which they answered this question on a continuous scale, in the

form of a slider, ranging from 0 to 100, with endpoints "*Not at all plausible [/likely]*" and "*Extremely plausible [/likely]*."[11] The intervals started from "*No more than 10 more years*" and "*At least 10, but no more than 20 more years*," and they ended with "*At least 80, but no more than 90 more years.*"[12]

In contrast, for participants in the cumulative distribution condition, the elicitation schedule was introduced as follows: "…*indicate how plausible [/likely] you consider it that you will live at least as long as the number of years given*." To maintain consistency with the probability density condition, this schedule also featured nine items, but these represented lower-bound survival thresholds rather than 10-year intervals. The items were answered on a scale identical to that in the probability density condition. The survival thresholds started from "*At least 10 more years*" and "*At least 20 more years*"— ending with "*At least 90 more years*."

Before ending the survey, participants indicated their demographics and received payment.

Results.

To arrive at an aggregate distribution of mortality beliefs, we first derived probability densities from the responses of participants in the cumulative distribution conditions.[13] Because participants across conditions likely held idiosyncratic interpretations of the plausibility and likelihood scales in the elicitation schedules, we standardized their responses to a common scale of probability density. Assuming that the sum of their likelihood and plausibility responses, respectively, could be interpreted as the entire probability of dying—that is 1.0—we divided the responses for the age ranges by the sum of their nine responses to obtain standardized probability

[11] The default response—if participants merely were to click on the slider, but not move it—was zero.
[12] We attempted to pick age-ranges that were plausible *prima facie* for our targeted sample, which consisted mostly of students in their mid-twenties.
[13] Before analysis, we excluded one participant who indicated only zero plausibility/likelihood for all age ranges. In addition, eight participants in the cumulative density condition were omitted from the analysis as they indicated non-monotonic cumulative distribution functions, making it impossible to derive non-negative probabilities of death.

densities. We conducted all subsequent analyses using these probabilities. The sample averages of these probabilities across ages are shown in figure S5 below, in which is also shown a curve representing the best-fit Weibull distribution (fit not rejected by W test, $p>.25$)

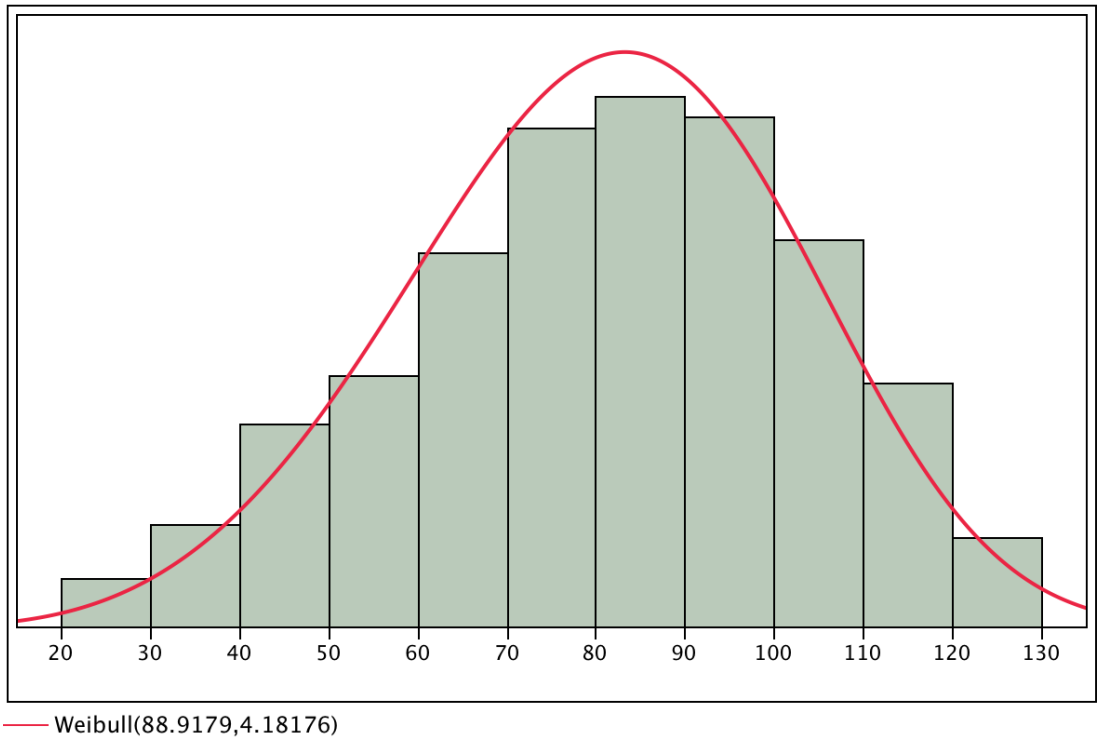


Figure S5. The elicited belief distribution of our German sample, with a fitted Weibull distribution (red line; numbers in parentheses are scale and shape parameters, respectively).

In figure S6, we present belief data together with fitted curves showing best-fit Weibull distributions that compare cumulative distribution versus probability density judgments; and in figure S7, elicitations in the form of likelihood versus plausibility. In either case, the two pairs of estimated parameters for the Weibull curve are not statistically distinguishable, $ps > .05$. We therefore present in our subsequent analyses belief distributions that are aggregated across the experimental conditions.

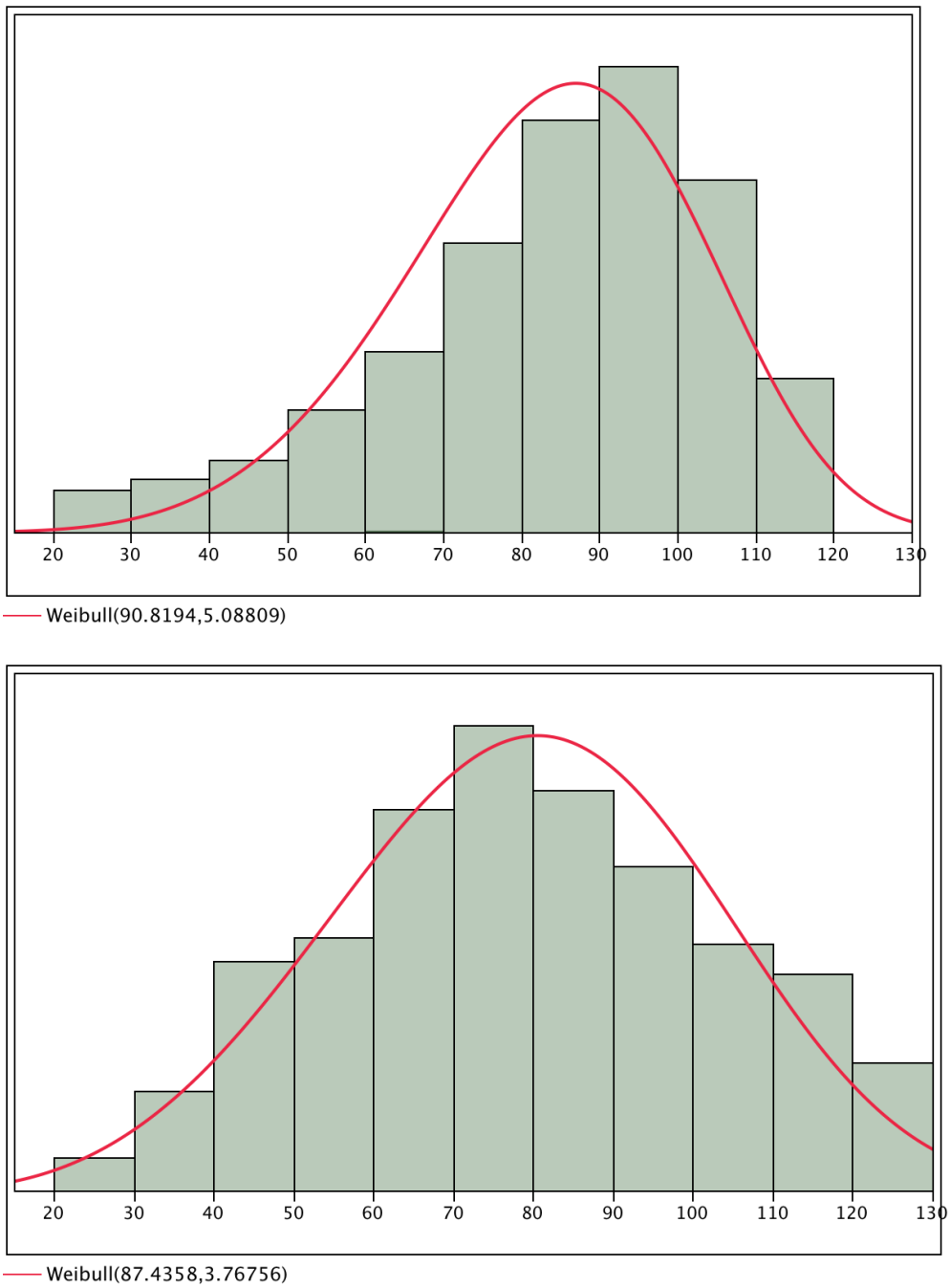
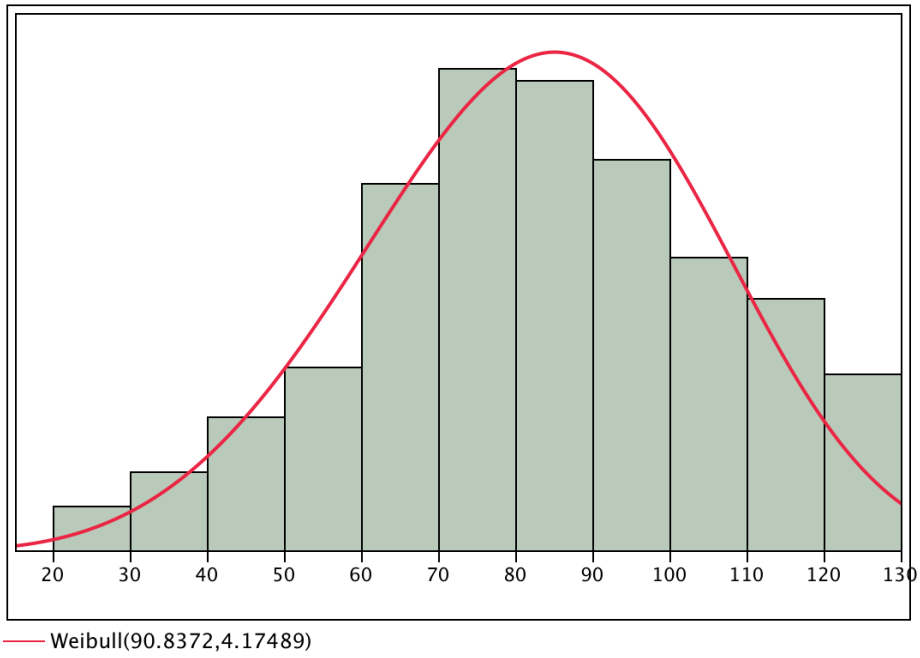


Figure S6. Results from Study 1. Elicited belief distributions (green) with Weibull curves fitted to the data (red). Numbers in parentheses are scale and shape parameters, respectively. The two diagrams show the effect of cumulative distribution (upper panel) vs. probability density (lower

panel) elicitation. The estimated parameters of the fitted Weibull distributions are not significantly different in either case, *p*s>.05.



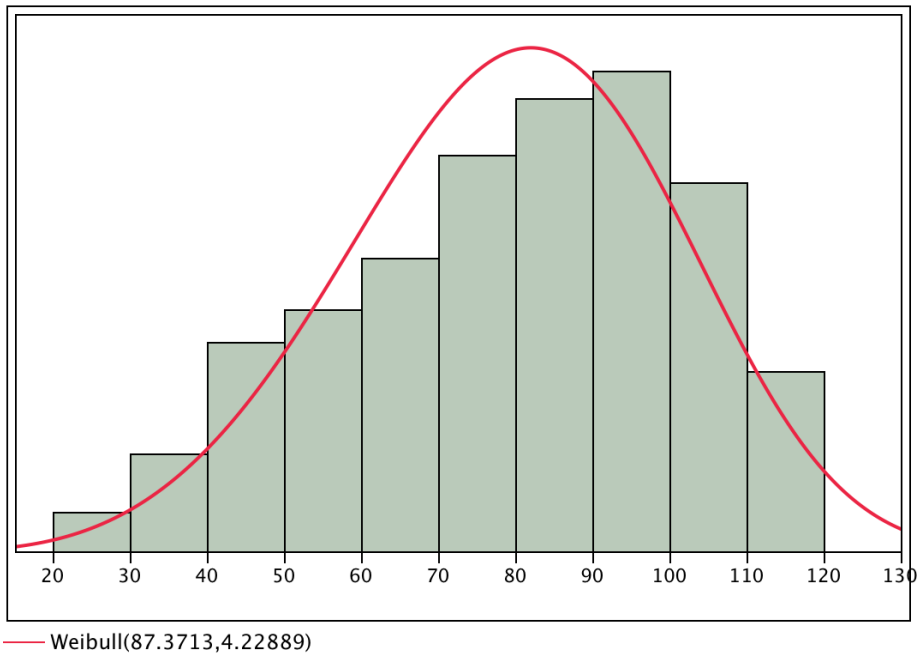


Figure S7. Results from Study 1. Elicited belief distributions (green) with Weibull curves fitted to the data (red). Numbers in parentheses are scale and shape parameters, respectively. The two

diagrams show the effect of likelihood (upper panel) vs. plausibility (lower panel) elicitation. The estimated parameters of the fitted Weibull distributions are not significantly different in either case, *p*s>.05.

Study 2.

Procedure.

The procedure for study 2 was similar to that employed in study 1, the major difference being that we used only one of the four types of distribution elicitation methods. Because we found little difference among responses to our two variations (PDF vs. CDF, and plausibility vs. likelihood, respectively), we decided to keep the elicitation method constant. In this study, we used the probability density method rather than the cumulative distribution method; it does not constrain responses to monotonicity, has been shown to be easier to understand (Chesley, 1975), and constitutes the representation that we are ultimately interested in. Further, respondents reported their beliefs in terms *plausibility* rather than *likelihood*. We considered this formulation to represent a less technical and more natural means of expression for our participants and hoped that it would avoid any potential confusion (e.g., the potential inference that the reported beliefs needed to add to a constant sum across all ranges). In addition, from a statistical point of view, the concept of likelihood may be interpreted as a form of plausibility (Anscombe & Aumann, 1963).

For this study we used the same elicitation schedule as shown above in figure S3. It was administered over the internet to participants recruited through the online panel of Amazon Mechanical Turk.[14] In exchange for participation we paid respondents $1; the survey lasted approximately 10 minutes.

[14] The sample consisted of 36% females and 64% males; average age was 25.9 years, *SD* = 5.5.

***Results*.**

In figure S8 below we show the same aggregated results as for our German sample above, and again a fitted Weibull distribution (*W* test $p>.25$ indicating non-rejected fit).

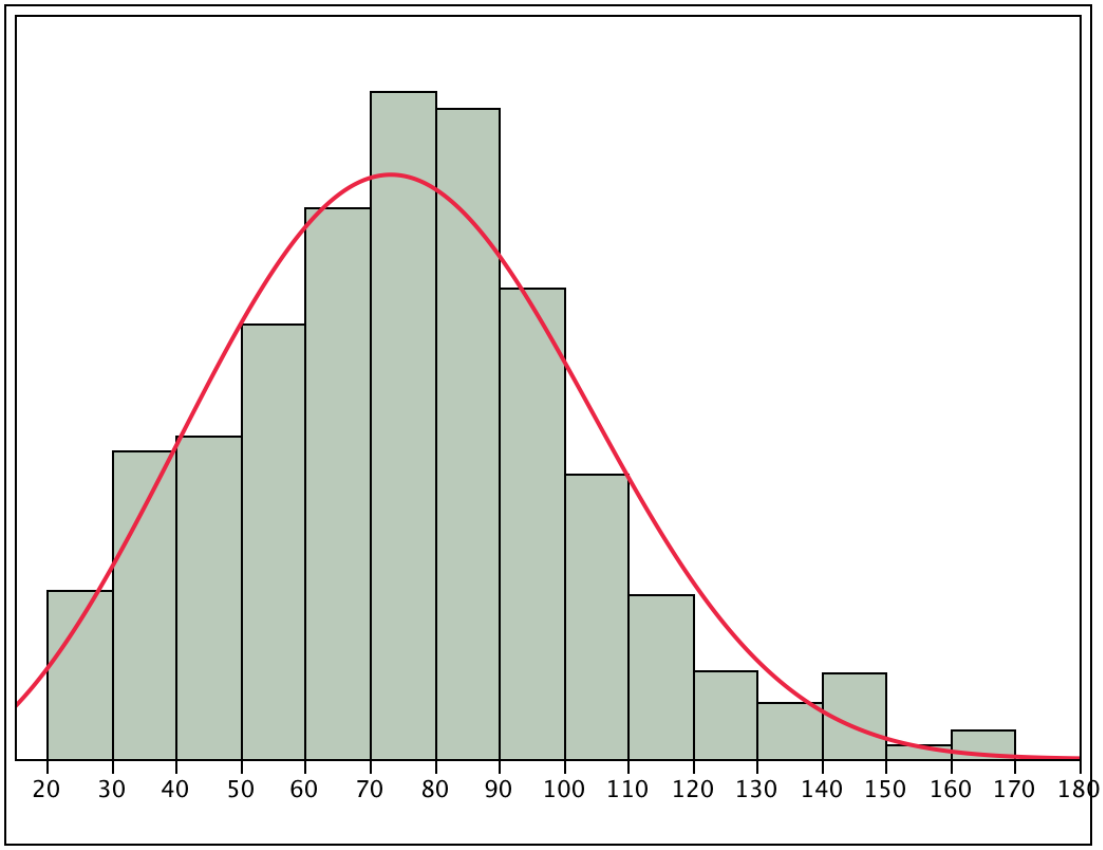


Figure S8. The elicited belief distribution of our U.S. sample, with a fitted Weibull distribution (red line; numbers in parentheses are scale and shape parameters, respectively).

Correction For Remaining Life Expectancy

In the construction of our aggregate results for subjective beliefs, each individual's contribution to the overall density was weighted by the proportion of probability mass remaining given her age. That is, using the overall distribution of deaths in the population, an 80-year old would have roughly half her probability mass left (being roughly equally likely to have already

died, as she is to dying in the future), and so would have her contribution to the aggregate weighted a factor of roughly one half. Had this weighting not been performed, older individuals would have had a disproportionate influence on the aggregate results, as their entire probability mass (which of course is 1 for each indivdual, given that individual responses are conditional on already having reached their current age) pertains to a shorter remaining lifespan than does that of younger individuals. It should be noted that this correction was performed using gender-specific life tables to correct for the somewhat greater probability that women live until a very old age, and the somewhat greater mortality at young ages that men exhibit. This is especially important for the U.S. sample (Study 2), where this pattern is more pronounced.

Forecasts

To obtain a more conservative basis for assessing the exaggerated probabilities of dying at a very old age, we produced forecasts for how the distribution of deaths might change in the future. We made two such forecasts, for the years 2070 and 2132; each was based on HMD (2012) life tables for 2009 and constructed using the Lee-Carter method (Lee & Carter, 1992), commonly used in the demographics literature. The forecasts were produced using the 'demography' package (Hyndman et al., 2012) of the R statistical programming language.

After arriving at the new, forecasted, life tables, we fitted Weibull distributions to both of them, as above. As can be seen in the main article's figures 1 and 3, the distribution of deaths shows a progressively pronounced peak as it is forecast farther into the future; deaths are shown as likely to become more and more concentrated around a central mode, with most of the improvement in expectation coming from a decreasing proportion of deaths at younger ages, while there is little increase in the proportion of deaths occurring at very old ages (above approximately 105 years of age).

The fitted Weibull distributions to both countries for both future years fit well (*W* test *p*s>.25). Notably, we are here fitting only the 92 data points (one each, for ages 18 to 109) produced by the forecast, in contrast to the millions of points when we are fitting similar models to the population deaths data above. This may account for the improved fit statistics.

The parameters produced from this exercise, and the resulting expectations (i.e., means), are presented in table S1:

Table S1

Estimates of Weibull parameters and means for forecasted changes in life expectancy.

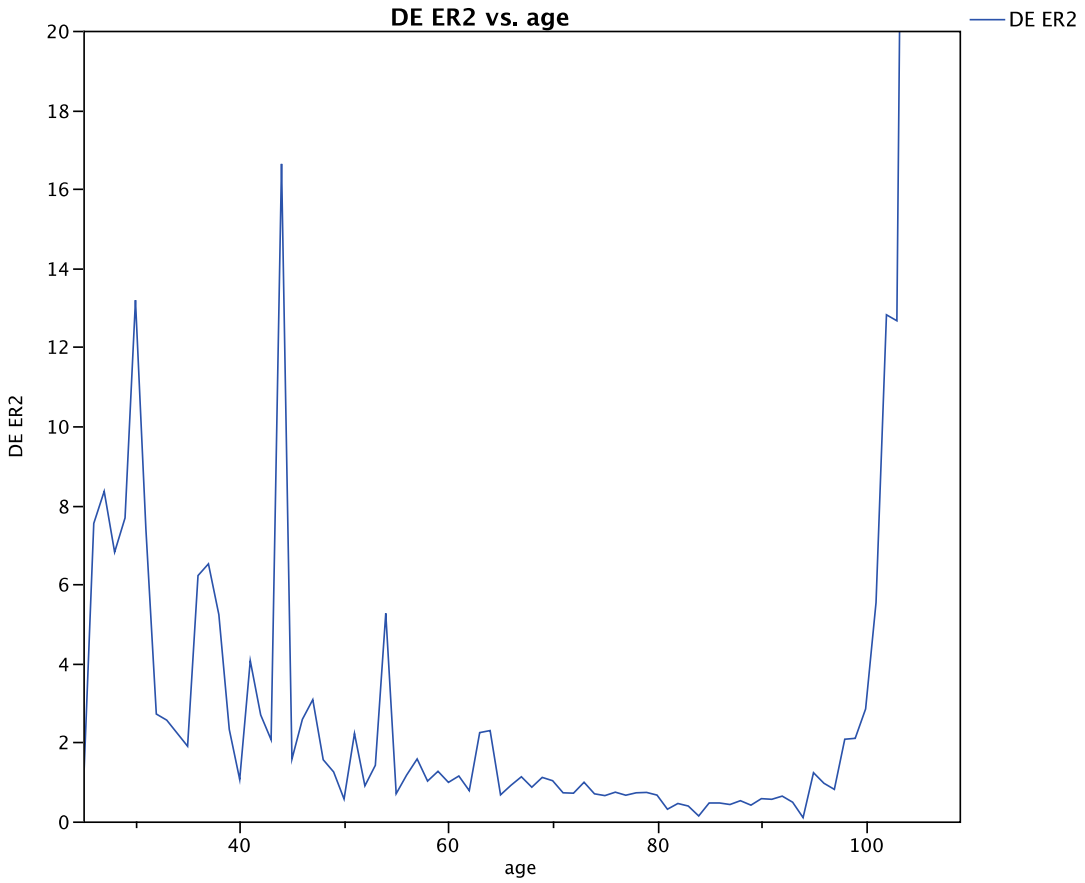
	year	scale	shape	mean
Germany	2070	93.51	13.15	89.7
	2132	97.52	19.21	94.8
U.S.	2070	90.71	10.00	86.1
	2132	94.33	14.50	90.7

Error Ratios

In addition to the error ratios (i.e., the ratio of probabilities based on our Weibull model of subjective beliefs to life table probabilities) given in the main text in figures 2 and 4 (for Germany and the U.S., respectively), we also performed two variations on the same calculations, respectively replacing the Weibull model with raw belief probabilities, and replacing the life table probabilities with a Weibull model fitted to them. The former variation produces noisier ratios, as it is based on raw data rather than a fitted model, while the latter has the issue, noted above, regarding lack of statistically significant fit statistic from our population data sets.

Moreover, a Weibull model fitted to the life table probabilities produces a left tail that is thinner than that revealed by the raw data. For estimating error ratios at lower ages, therefore, the raw data represents a more conservative standard. Using Weibull models both for beliefs and the

populations produces smoother error ratio curves, and show much greater pessimism at younger ages. The higher degree of pessimism could, however, be an artifact of the Weibull underestimating the thickness of the left tail, as mentioned above. For the purpose of completeness, figure S9 and S10, respectively, show the two additional cases.



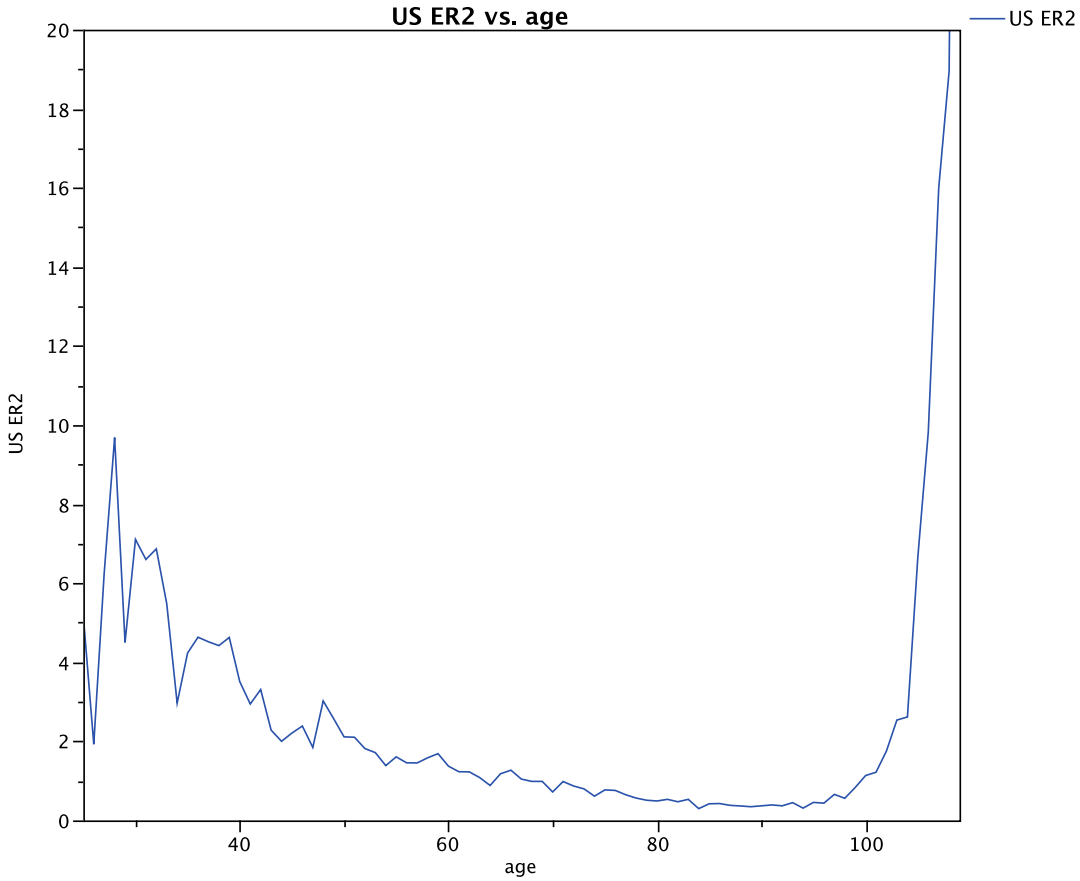
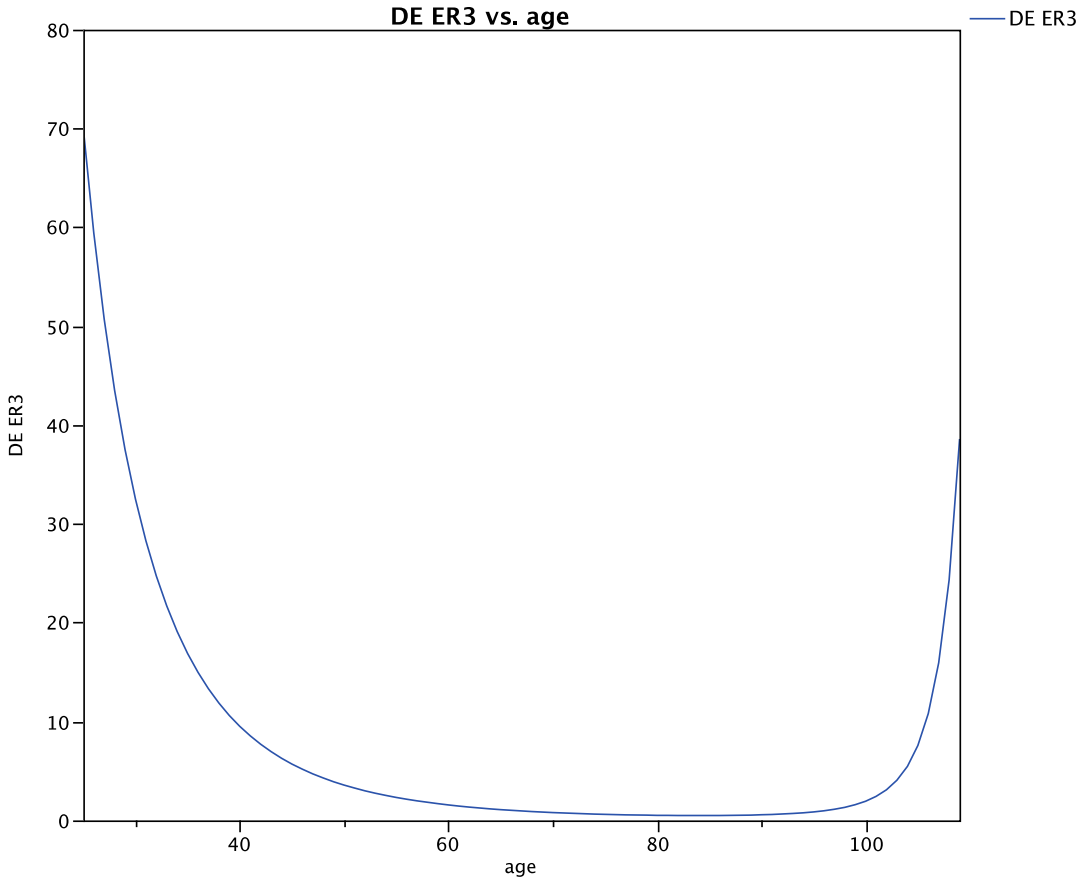


Figure S9. Error ratios of beliefs relative to life table data using raw probabilities; Germany (upper panel), U.S. (lower panel); 2009.


DE ER3 vs. age
DE ER3
DE ER3
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70
60
50
40
30
20
10
0
40
60
80
100
age

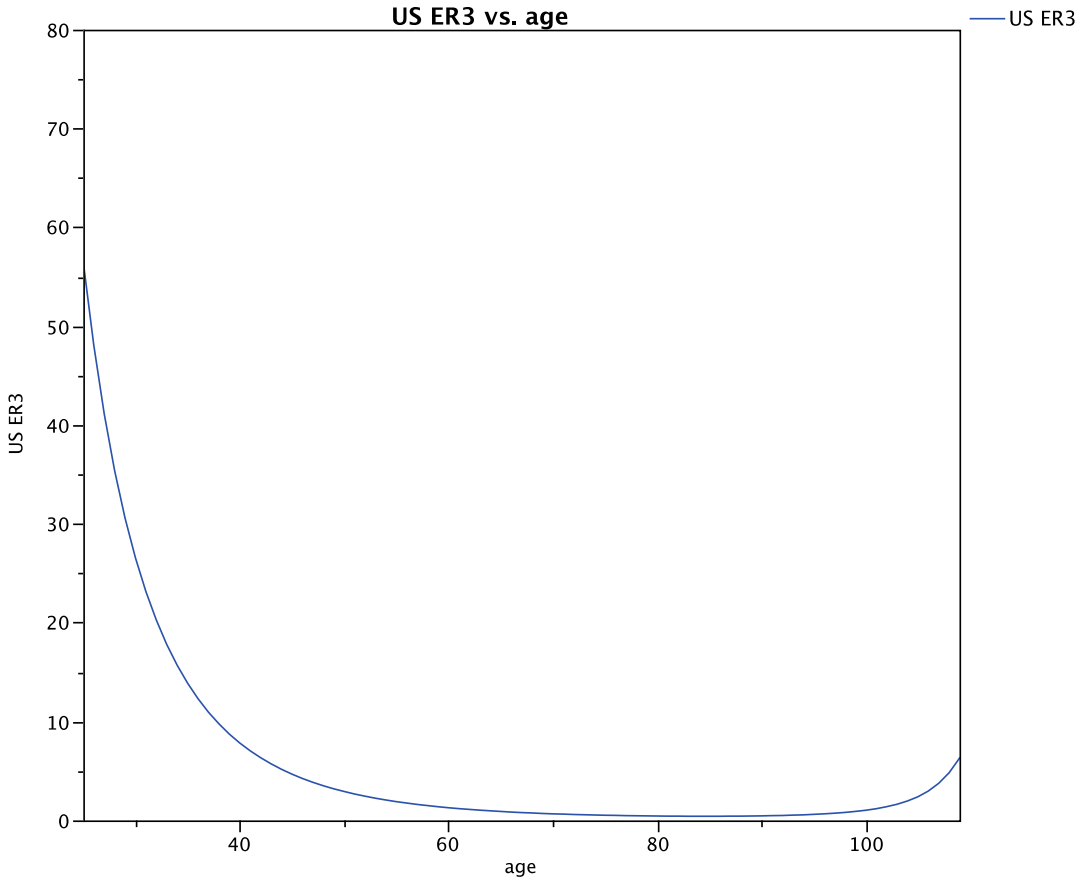

Figure S10. Error ratios of beliefs relative to life table data using Weibull models; Germany (upper panel), U.S. (lower panel); 2009.

Both cases, for both populations, display the same basic pattern of overestimation of the likelihood of dying both at young ages and at very old ages. This is consistent with our main analysis.

Comparison to Point Estimates

To check our results for robustness to asking each respondent for only one probability at a time, rather than eliciting probabilities for the entire lifespan of each respondent, we conducted a supplementary survey. This was also to establish that our main respondents are not relying on a 'visual' heuristic for reporting their answer, or that another artifact of our elicitation procedure is not driving our results.

We conducted this study with an online sample of 300 participants in the US, with ages ranging from 18 to 65 (mean 33). Each participant was asked to report her perceived probability of dying in the next five years, using a slider from 0 to 100.

Aggregating the results from this survey, we find a similar pattern of results as in our main studies. In fact, figure S11 indicates that the exaggeration of probabilities reported for the chance of dying at young ages is even more pronounced than what we saw before: from the early twenties to the early forties we observe error ratios roughly between 10 and 50. As before, we then see an increasingly accurate calibration of beliefs as age approaches 70. As our oldest respondent in this sample is 65, we cannot verify whether the pattern at very old ages holds. Nevertheless, the results that we do observe lend further credence to our elicitation method.

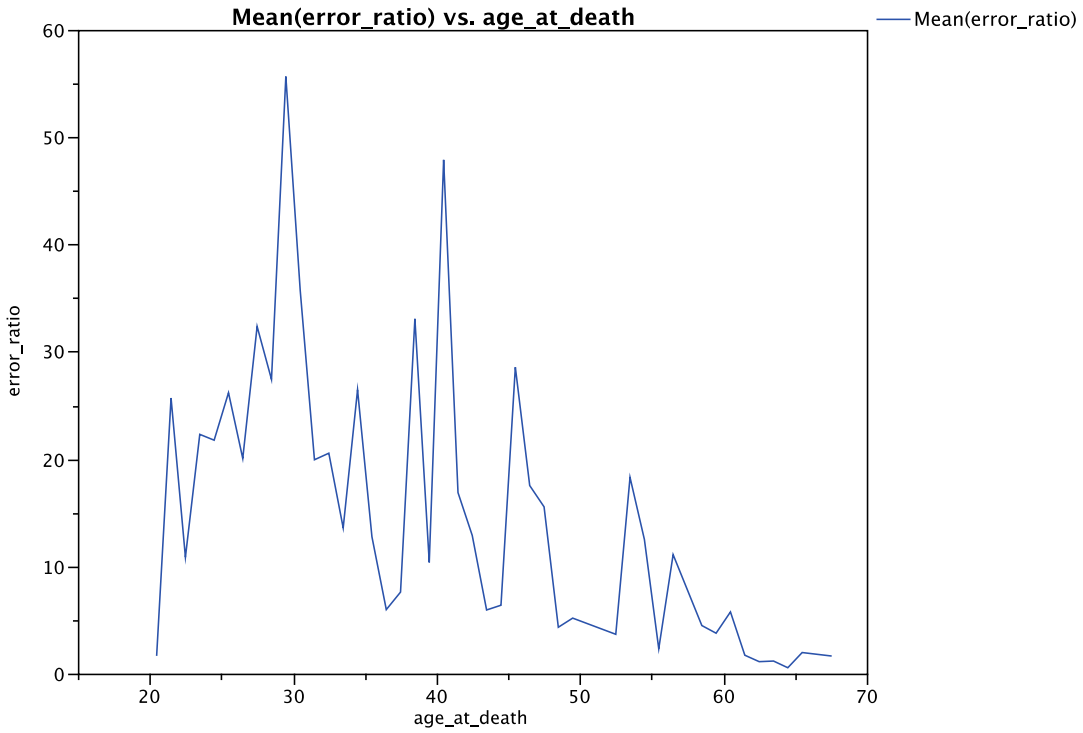

Figure S11. Error ratios for a supplementary study using a single estimate per respondent.

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