Visualising Uncertainty

David Spiegelhalter

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Fields Institute, May 28th 2009

With thanks to Mike Pearson, Ian Short , Yin-Lam Ng, Hauke Riesch, Owen Smith, Arciris Garay, etc etc

Communicating uncertainty

- Probabilities of events
- Uncertainty about continuous quantities
- Uncertainty about risks

using

- Text (words and numbers)
- Graphics
- Animation

- Recently I went to see my GP …

Online Clinical Calculator

Coronary Heart Disease Risk Calculator

Risk Factor	Your Answer	Points	Relative Risk
Sex:	◉ Male ○ Female		
Age:	54 years	3	
Smoker:	○ Yes ◉ No	0	Low
Diabetes:	○ Yes ◉ No	0	Low
Blood Pressure:	148 / 94 mm Hg	2	High
Total Cholesterol	224 mg/dl	1	Moderate
HDL Cholesterol:	54 mg/dl	0	Low

Calculate, with Incomplete Values | Calculate

Total Points: 6 = 10 **% risk of heart disease in 10 years**

Average 10-year risk = 14 **%** *(for others in your age group)*

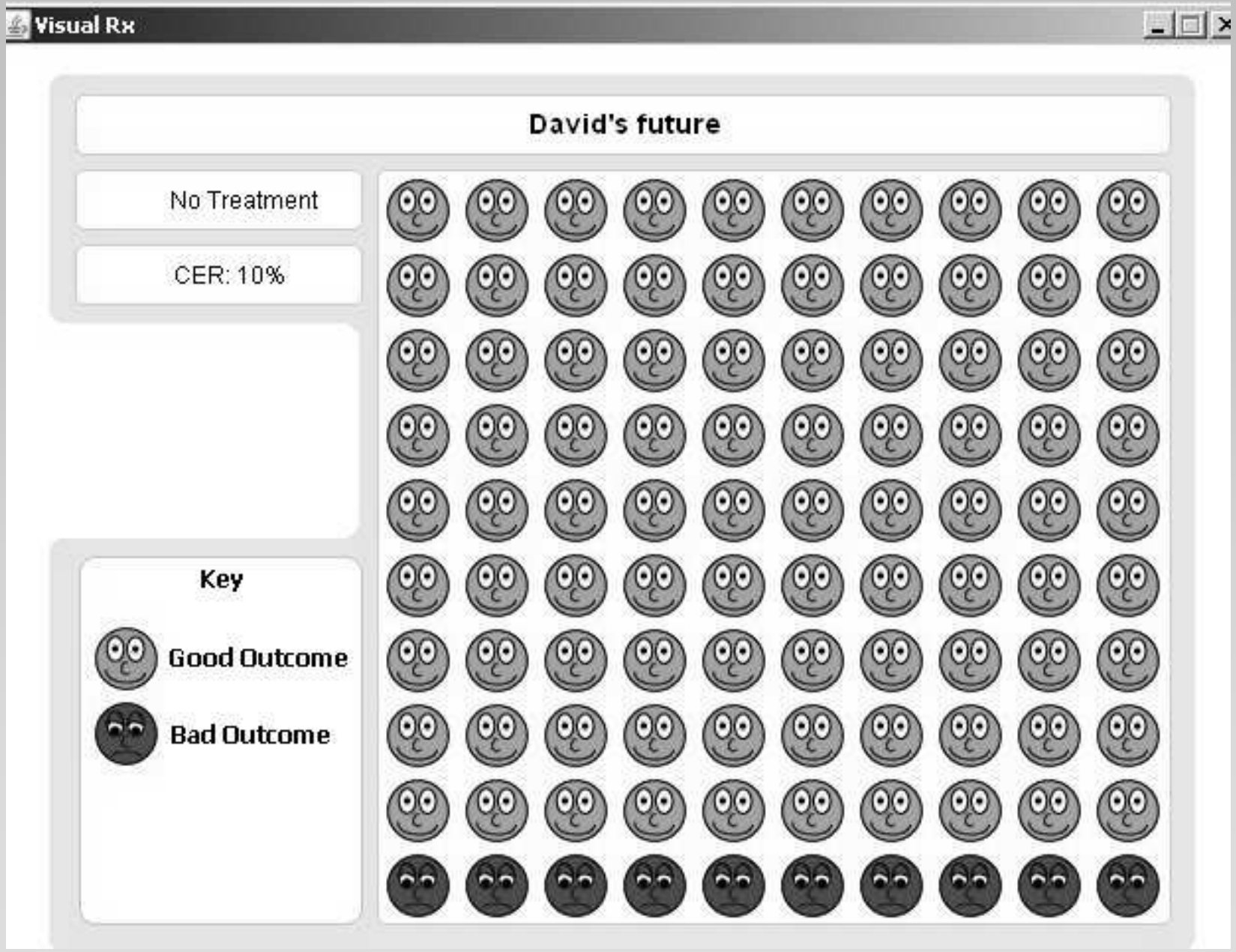
Low 10-year risk = 6 **%** *(for others in your age group)*

Information for this Coronary Heart Disease Risk Calculator comes from the Framingham Heart Study. The results are applicable *only* for the ages of 30 t
Please refer to:

Wilson, PW, *et. al*. **Prediction of Coronary Heart Disease Using Risk Factor Categories**. *Circulation* 1998 97 (18): 1837-1847.

My doctor quoted me a 10% risk of heart attack or stroke in 10 years

Smileys / crowd chart *without* statins



Some choices

- Absolute / relative risks /NNT?
- Interpretation of probability?
- 0.8, 80% or 80 out of 100?
- Positive or negative frame?
- Pie chart, bar chart, smilies etc?

- Absolute or relative risks?

Numerators and denominators

Win $1 for picking a red bean

53% pick from here

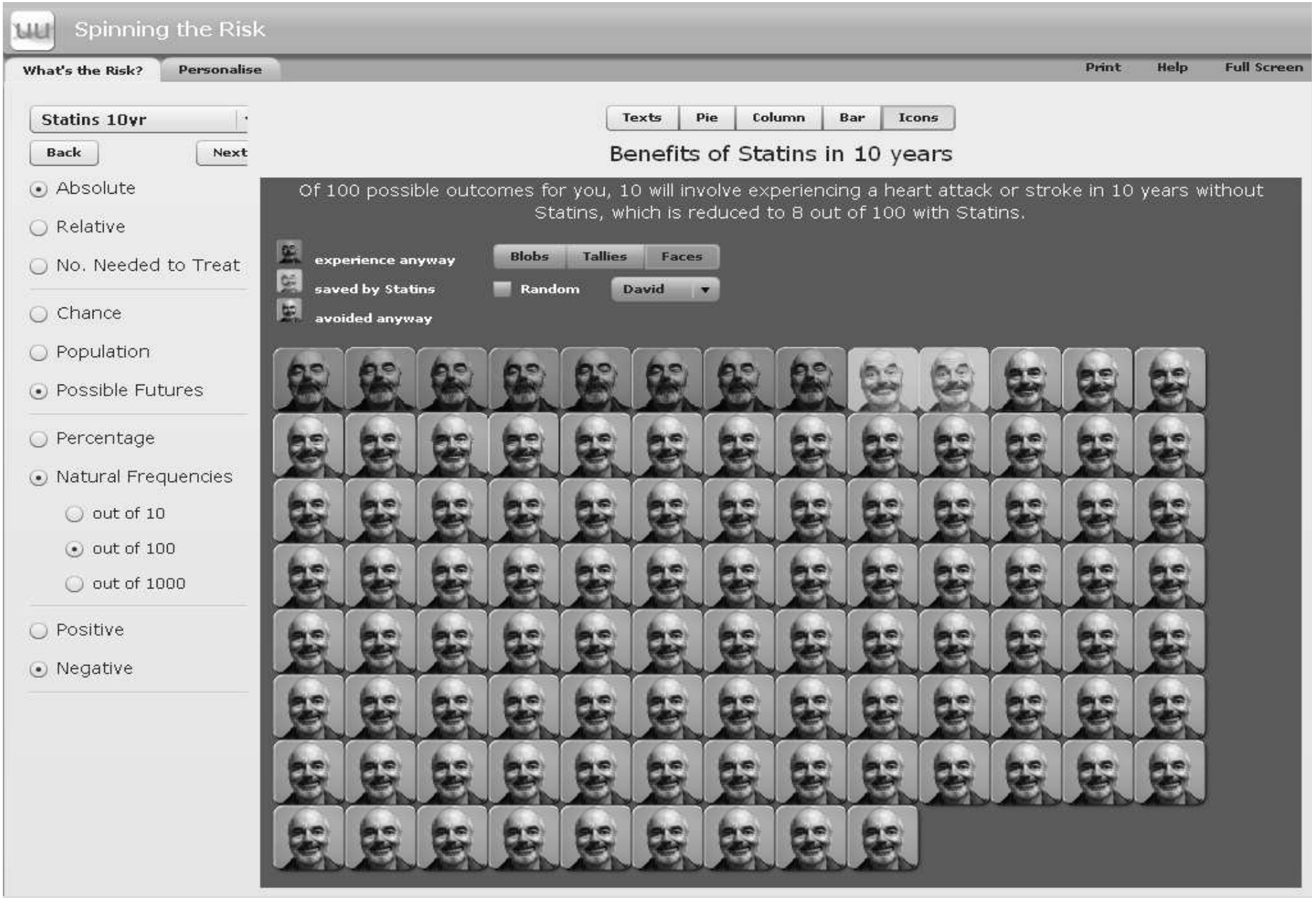
10% red beans

8% red beans

(Denes-Raj & Epstein, 1994)

Real story:

1 in 10 people carry a low-risk gene



Spinning-the-risk: www.understandinguncertainty.org/node/233

The great bacon sandwich debate

- World Cancer Research Fund (WCRF) issue report (600 pages) in October 2007 on the influences of nutrition and physical activity on cancer
- 50g of processed meat per day associated with a 20% increase in bowel cancer
- WCRF Website*:*
  "Try to avoid processed meats such as bacon, ham, salami, corned beef and some sausages"

The great bacon sandwich debate

The media reaction

Sun*:* *"Careless pork costs lives"*

Daily Mail*:* *"Now cancer experts add bacon, ham and drink to danger list"*

So what *does* it mean for individuals?

- Approximately 5% lifetime risk of getting bowel cancer
- 20% increase in risk means that eating a huge bacon sandwich each day increases this lifetime risk to 6%
- "*I'd rather shave a few years off my life with the occasional bacon sarnie than be 110 and dribbling into my All Bran*"

  Dr Keith Hopcroft, ***Sun***

Spinning-the-risk: www.understandinguncertainty.org/node/233

How long are you going to live?

Microsoft Excel - ILTUK0406Reg-7.xls

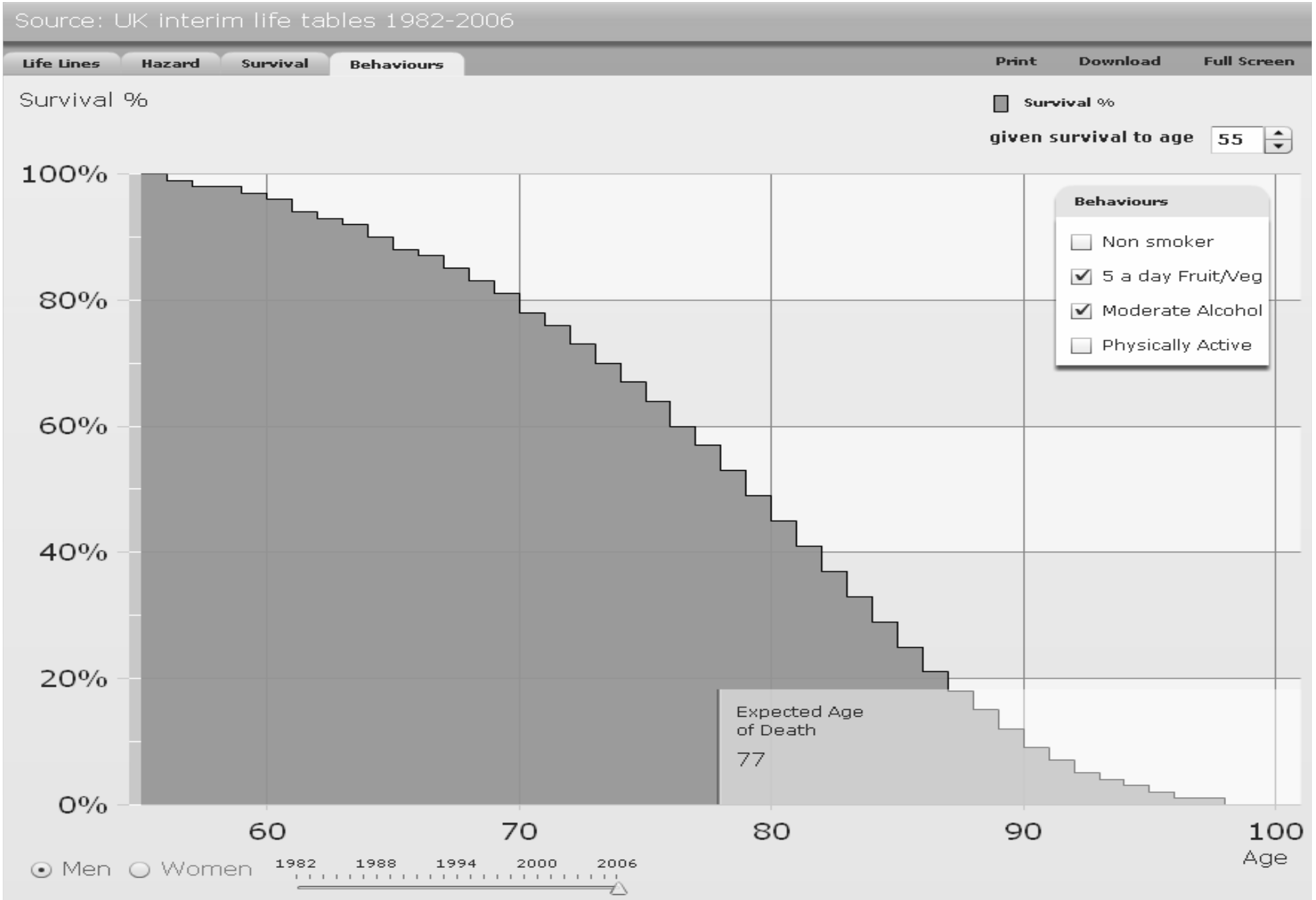
File Edit View Insert Format Tools Data Window Help Adobe PDF

A1 fx Interim Life Tables, United Kingdom

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**Interim Life Tables, United Kingdom**										**Back to contents**							
2																		
3	**Period expectation of life**										**Office for National Statistics**							
4	**Based on data for the years 2004-2006**																	
5																		
6	**Age**	**Males**						**Females**										
7	x	m_x	q_x	l_x	d_x	e_x		m_x	q_x	l_x	d_x	e_x						
8	0	0.005592	0.005576	100000.0	557.6	76.89		0.004564	0.004554	100000.0	455.4	81.26						
9	1	0.000408	0.000407	99442.4	40.5	76.32		0.000384	0.000384	99544.6	38.2	80.64						
10	2	0.000242	0.000242	99401.8	24.0	75.36		0.000186	0.000186	99506.4	18.5	79.67						
11	3	0.000184	0.000184	99377.8	18.3	74.37		0.000147	0.000147	99487.8	14.6	78.68						
12	4	0.000127	0.000127	99359.5	12.6	73.39		0.000117	0.000117	99473.2	11.7	77.69						
13	5	0.000114	0.000114	99346.9	11.3	72.40		0.000097	0.000097	99461.6	9.7	76.70						
14	6	0.000121	0.000121	99335.6	12.0	71.40		0.000110	0.000110	99451.9	11.0	75.71						
15	7	0.000095	0.000095	99323.6	9.4	70.41		0.000084	0.000084	99440.9	8.3	74.72						
16	8	0.000114	0.000114	99314.2	11.3	69.42		0.000087	0.000087	99432.6	8.6	73.72						
17	9	0.000119	0.000118	99302.9	11.8	68.43		0.000069	0.000069	99424.0	6.9	72.73						
18	10	0.000120	0.000120	99291.1	11.9	67.44		0.000084	0.000084	99417.1	8.3	71.73						
19	11	0.000126	0.000126	99279.2	12.5	66.44		0.000091	0.000091	99408.8	9.0	70.74						
20	12	0.000147	0.000147	99266.6	14.6	65.45		0.000119	0.000119	99399.7	11.9	69.75						
21	13	0.000170	0.000170	99252.0	16.9	64.46		0.000127	0.000127	99387.9	12.6	68.76						
22	14	0.000194	0.000194	99235.2	19.2	63.47		0.000132	0.000132	99375.3	13.1	67.76						
23	15	0.000257	0.000256	99216.0	25.4	62.48		0.000164	0.000164	99362.1	16.3	66.77						
24	16	0.000339	0.000339	99190.5	33.6	61.50		0.000219	0.000219	99345.9	21.7	65.78						
25	17	0.000556	0.000555	99156.9	55.1	60.52		0.000241	0.000241	99324.1	24.0	64.80						
26	18	0.000640	0.000639	99101.8	63.4	59.55		0.000271	0.000271	99300.2	26.9	63.81						
27	19	0.000667	0.000667	99038.5	66.0	58.59		0.000291	0.000290	99273.3	28.8	62.83						
28	20	0.000720	0.000720	98972.4	71.3	57.63		0.000284	0.000284	99244.5	28.2	61.85						
29	21	0.000672	0.000672	98901.2	66.5	56.67		0.000280	0.000280	99216.3	27.8	60.87						
30	22	0.000750	0.000749	98834.7	74.1	55.71		0.000281	0.000281	99188.5	27.9	59.88						
31	23	0.000811	0.000811	98760.6	80.1	54.75		0.000299	0.000299	99160.7	29.6	58.90						
32	24	0.000739	0.000738	98680.6	72.9	53.80		0.000281	0.000281	99131.0	27.9	57.92						
33	25	0.000824	0.000823	98607.7	81.2	52.83		0.000307	0.000307	99103.2	30.4	56.93						
34	26	0.000778	0.000778	98526.5	76.7	51.88		0.000342	0.000342	99072.8	33.9	55.95						
35	27	0.000855	0.000854	98449.9	84.1	50.92		0.000354	0.000354	99038.9	35.1	54.97						
36	28	0.000778	0.000778	98365.8	76.5	49.96		0.000386	0.000386	99003.8	38.2	53.99						
37	29	0.000894	0.000894	98289.2	87.8	49.00		0.000382	0.000382	98965.6	37.8	53.01						
38	30	0.000948	0.000947	98201.4	93.0	48.04		0.000434	0.000433	98927.7	42.9	52.03						
39	31	0.000986	0.000985	98108.3	96.7	47.09		0.000425	0.000425	98884.8	42.0	51.05						

Contents | 2004-06 | 2003-05 | 2002-04 | 2001-03 | 2000-02 | 1999-2001 | 1998-2000 | 1997-99 | 1996-98 | 1995-97 | 1994-96 | 1993-95 | 1992-94 | 1991-93

Ready



Survival: www.understandinguncertainty.org/node/76

Combined Impact of Health Behaviours and Mortality in Men and Women: The EPIC-Norfolk Prospective Population Study

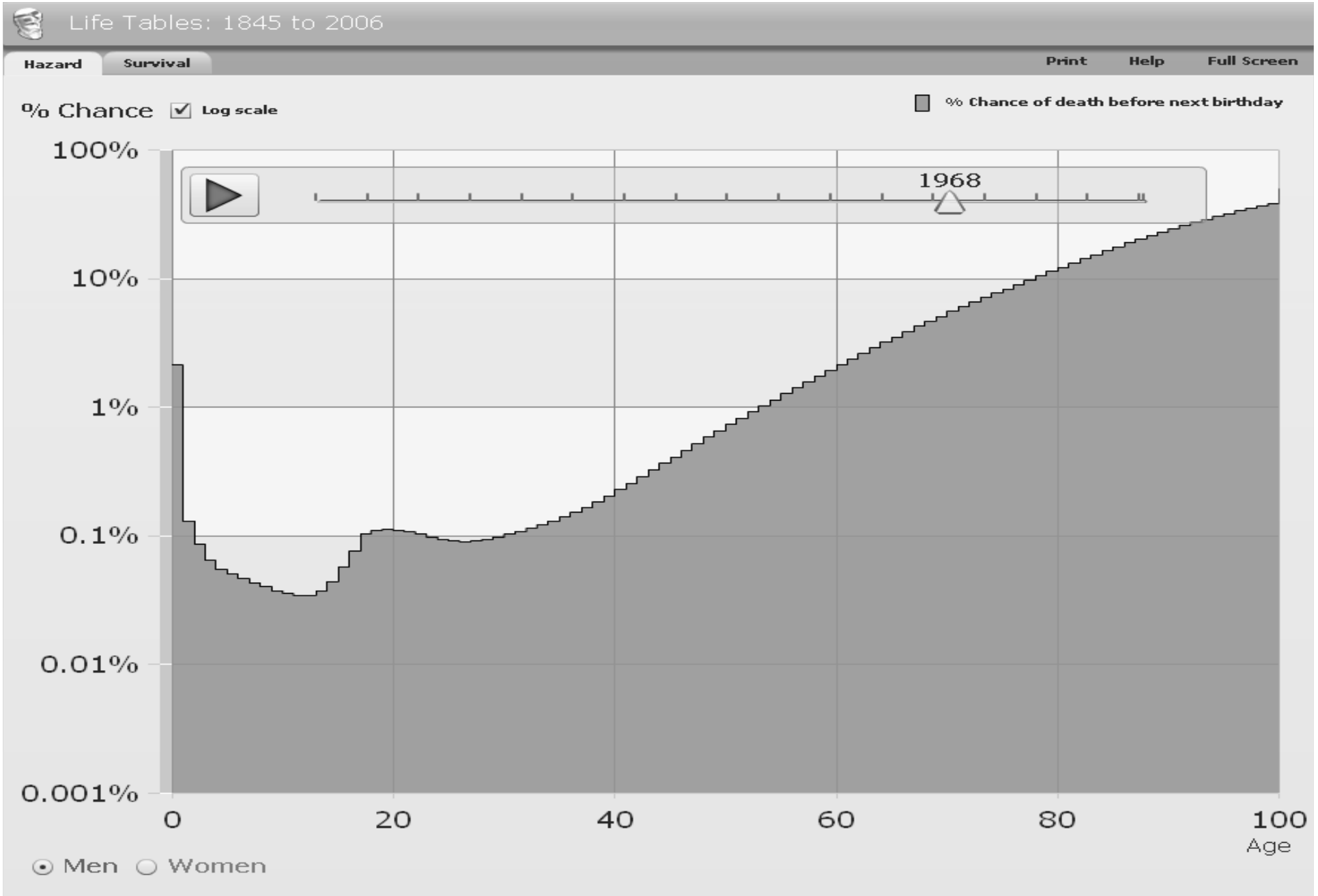
Kay-Tee Khaw[1*], Nicholas Wareham[2], Sheila Bingham[3], Ailsa Welch[1], Robert Luben[1], Nicholas Day[1]

Table 1. Health Behaviour Score: Score One Point for Each of the Health Behaviours Below for a Total Score of Zero to Four

Health Behaviour	How Scored
Smoking habit	Nonsmoker = 1
Fruit and vegetable intake	Five servings or more daily as indicated by blood vitamin C = ≥50 nmol/l = 1
Alcohol intake	One or more, but less than 14 units, a week = 1. One unit = approximately 8 g of alcohol; i.e., one glass of wine, one small glass of sherry, one single shot of spirits, or one half pint of beer
Physical activity	Not inactive = 1; i.e., if sedentary occupation, at least half an hour of leisure time activity a day; e.g., cycling, swimming; or else a nonsedentary occupation with or without leisure-time activity

Table 4. Mortality Rates and Relative Risk of All-Cause Mortality by Number of Health Behaviours, Adjusted by Age, Sex, and Body Mass Index, and Stratified by Cause, Sex, Age, Body Mass Index, and Social Class in 20,244 Men and Women Aged 45–79 y without Known Cardiovascular Disease or Cancer in EPIC-Norfolk 1993–2006, Cox Regression Model

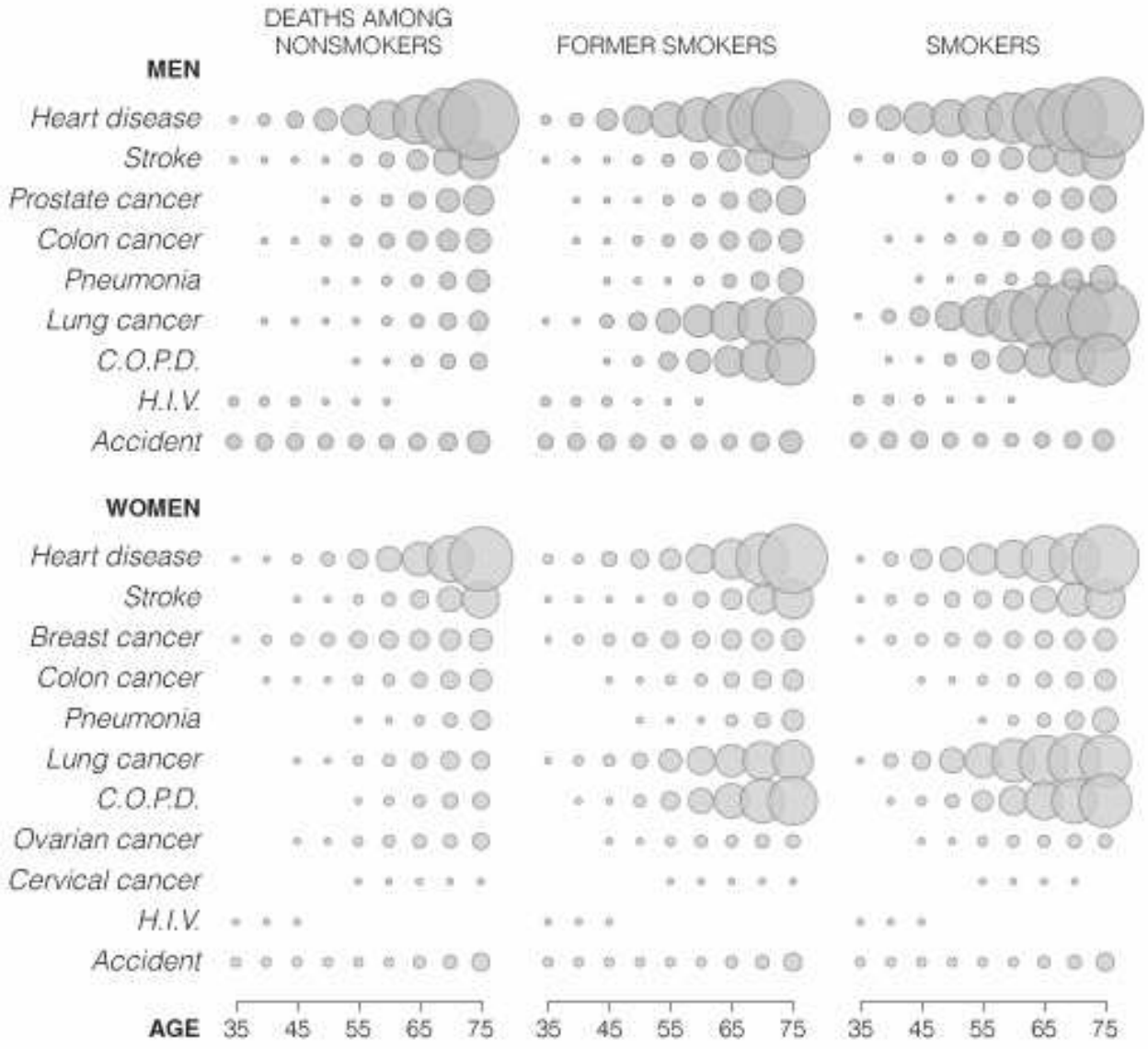
Mortality	Category	No. of Events/*n*	Number of Health Behaviours				
			4 (*n* = 6,285)	**3 (*n* = 7,788)**	**2 (*n* = 4,568)**	**1 (*n* = 1,407)**	**0 (*n* = 196)**
Mortality rate (*n*)	—	—	5.1 (318)	8.8 (682)	14.3 (651)	19.7 (277)	25.0 (49)
By cause	All cause	1,977/20,244	1	1.39 (1.21–1.60)	1.95 (1.70–2.25)	2.52 (2.13–3.00)	4.04 (2.95–5.54)
	Cardiovascular	676/20,244	1	1.59 (1.23–2.06)	2.47 (1.91–3.19)	3.36 (2.49–4.51)	5.02 (2.93–8.61)
	Cancer	839/20,244	1	1.21 (0,99–1.48)	1.81 (1.48–2.22)	1.94 (1.48–2.54)	3.74 (2.34–5.98)
	Non-CVD, noncancer	462/20,244	1	1.53 (1.16–2.03)	1.66 (1.23–2.24)	2.70 (1.92–3.82)	3.56 (1.77–7.16)



Past survival: www.understandinguncertainty.org/node/210

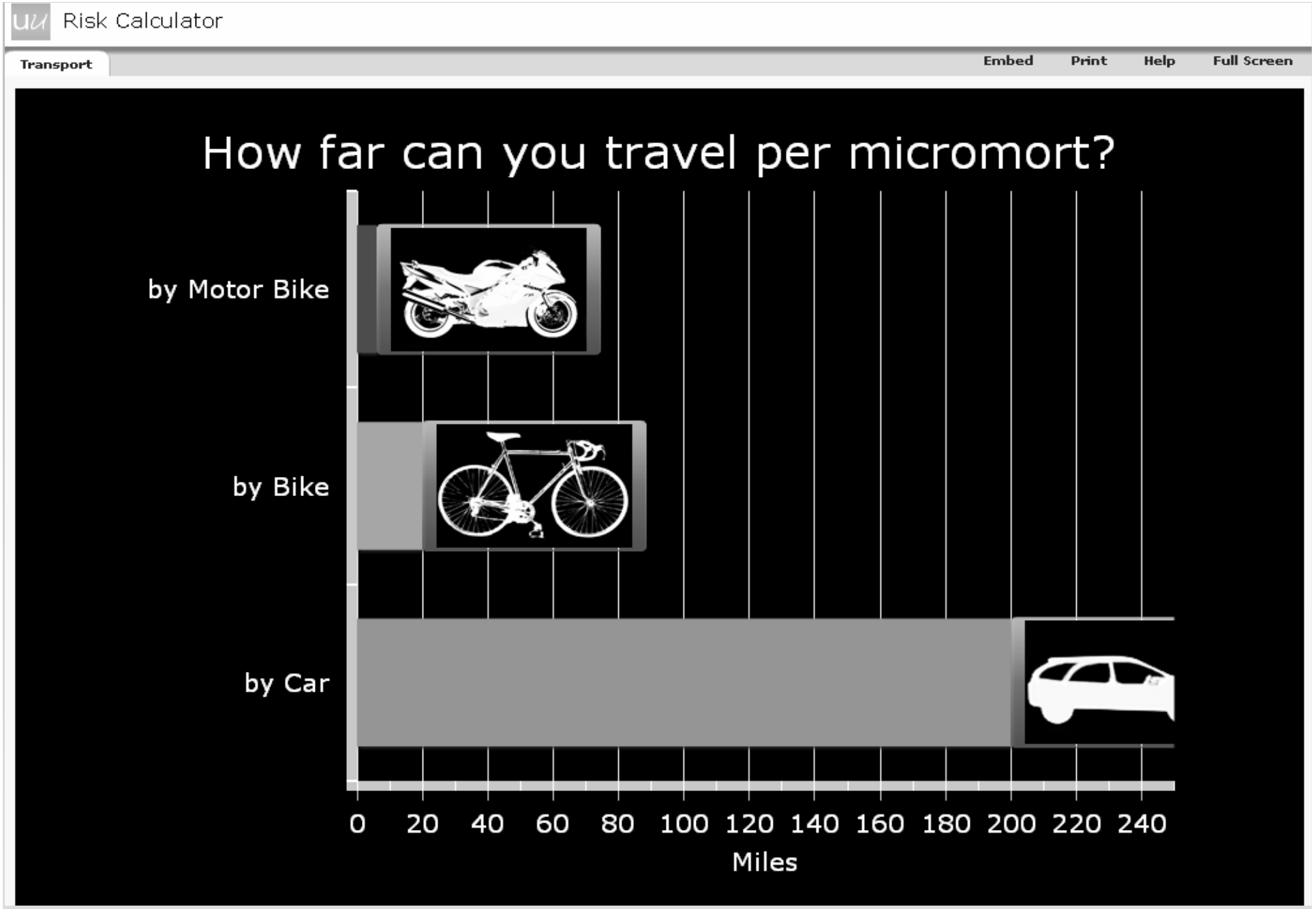
The New York Times

September 1, 2008



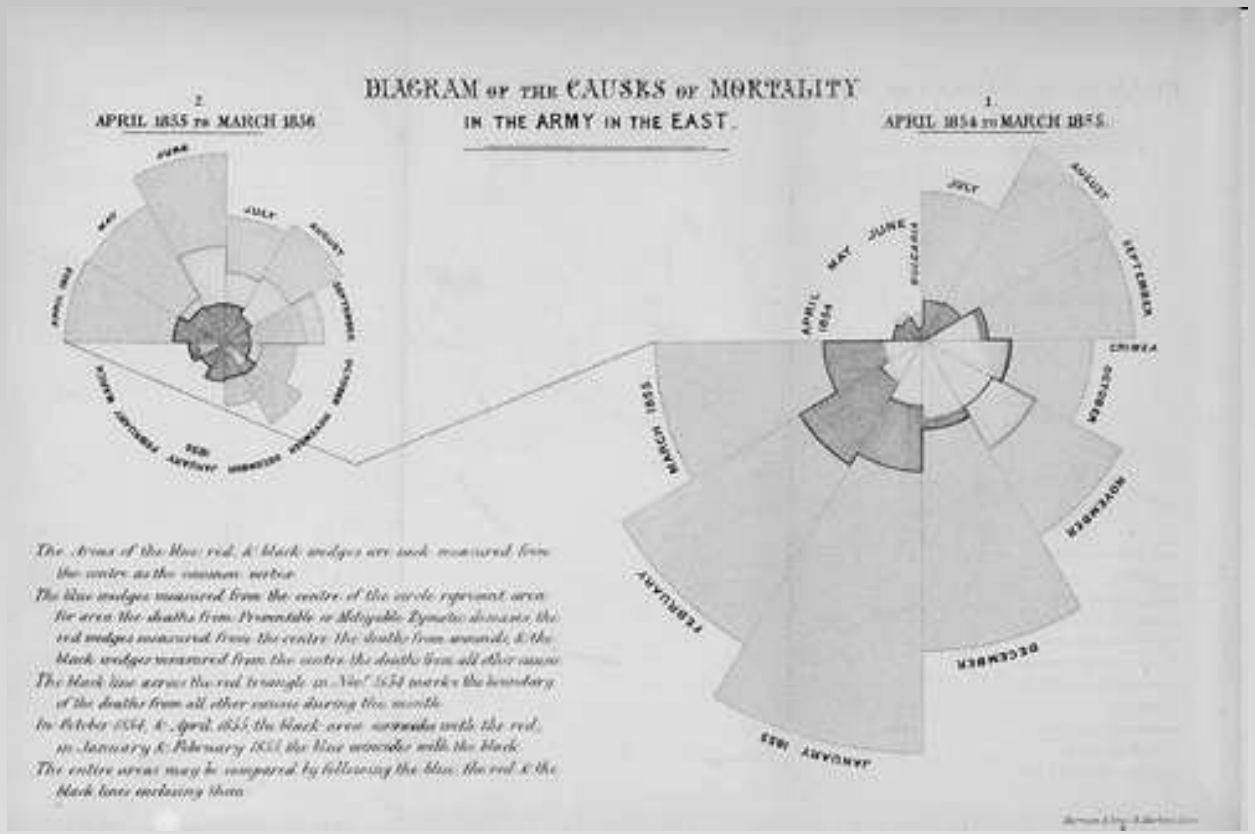
What are the risks?

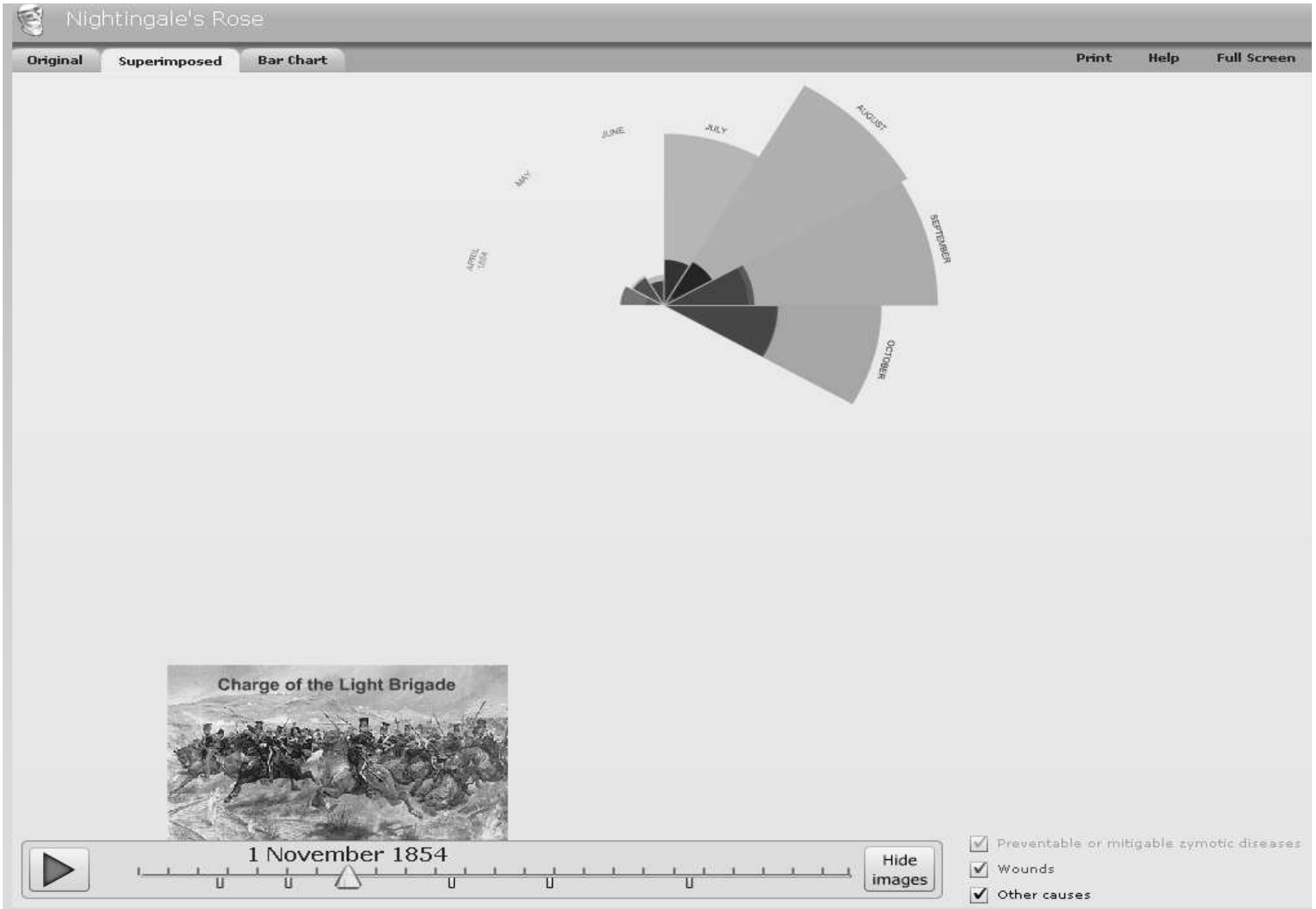
- Need a friendly unit of deadly risk
- A ***Micromort*** is a 1-in-a-million chance of dying
- Each day 50 people are killed in England and Wales (about 50 million)
- So just living means that we experience a micromort every day (on average)



Micromort animation:

Florence Nightingale (1820-1910)





Nighingale: www.understandinguncertainty.org/node/213

Formats for risk communication

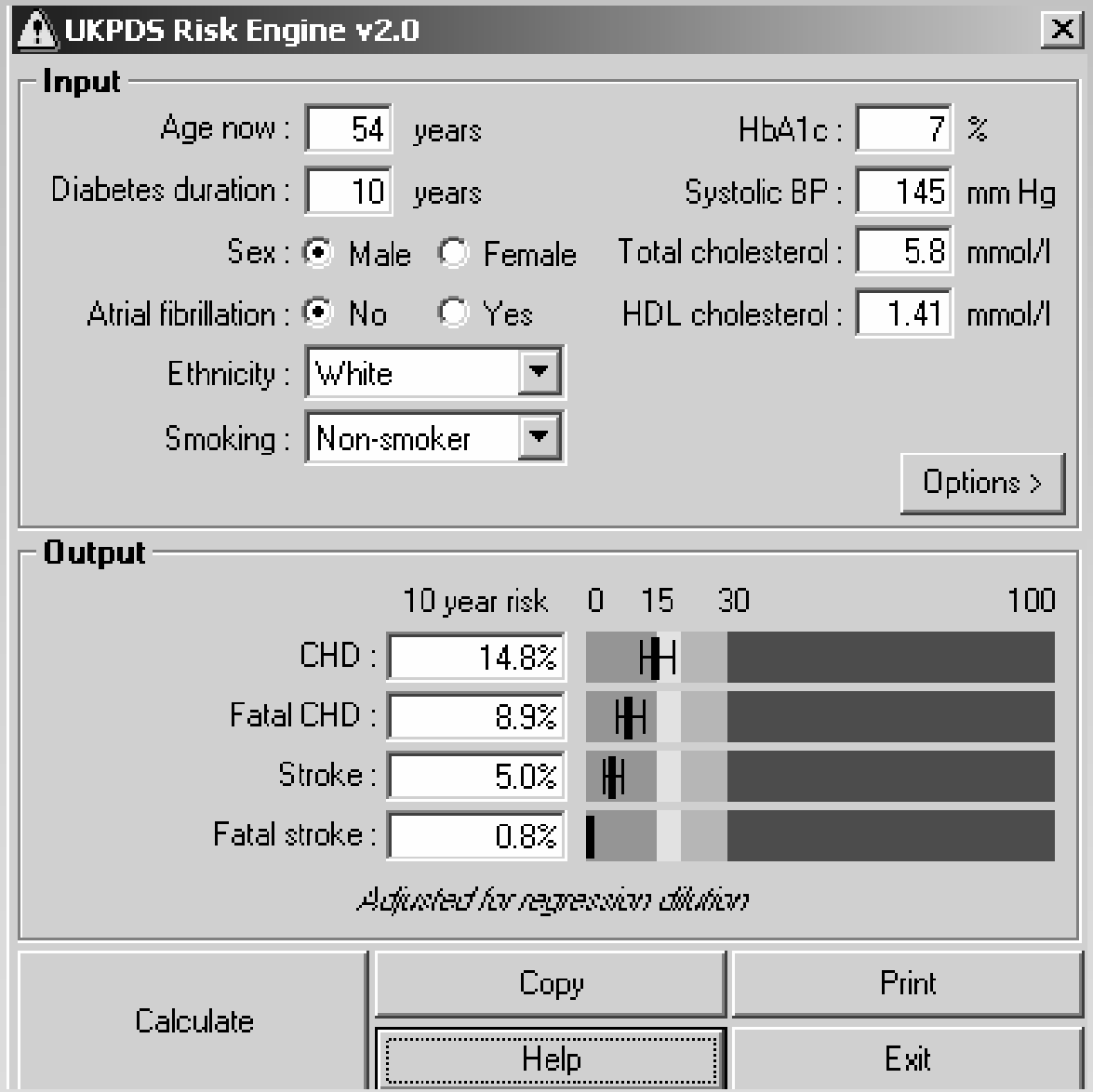
We may be concerned with what people –

- like
- understand / can reproduce
- are influenced by

But

- These are not necessarily the same formats!
- Formats are influential
- People vary hugely in their preferences and understanding

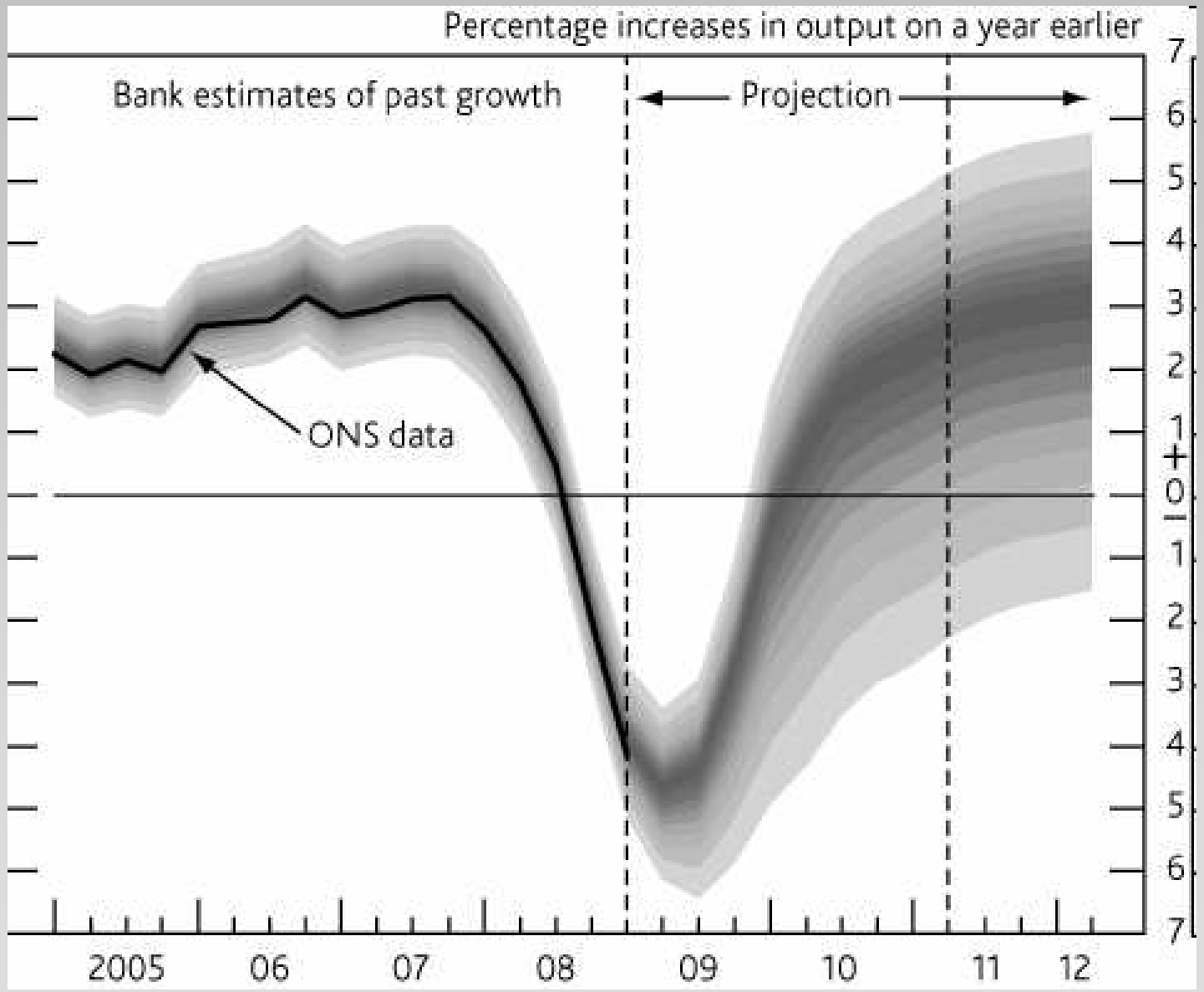
UKPDS risk engine



Problems with confidence limits

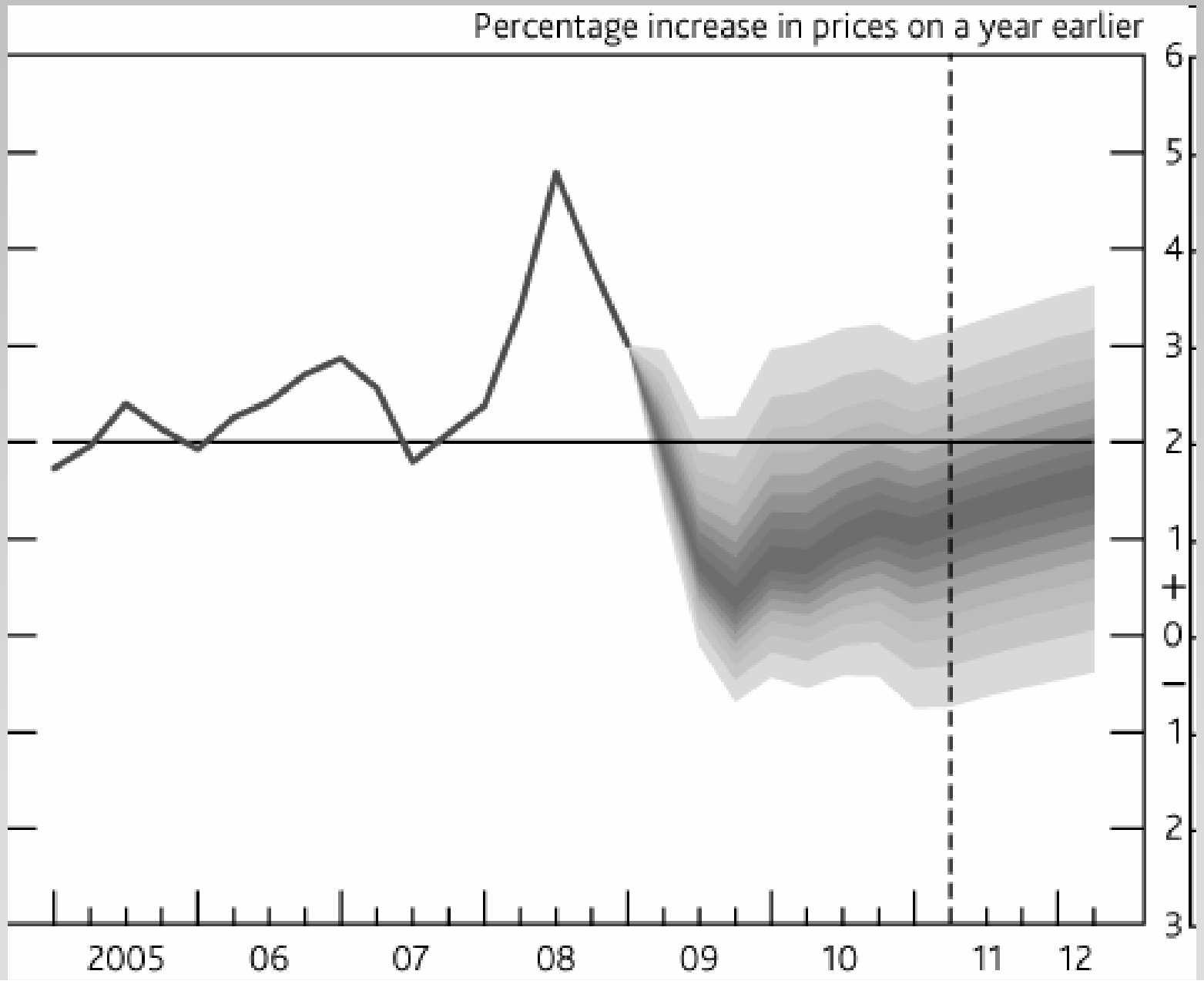
- Suggestion that all points in interval are equally likely
- Media can report “up to X people might have Hepatitis C”

Express as a probability distribution, such as Bank of England fan charts for GDP



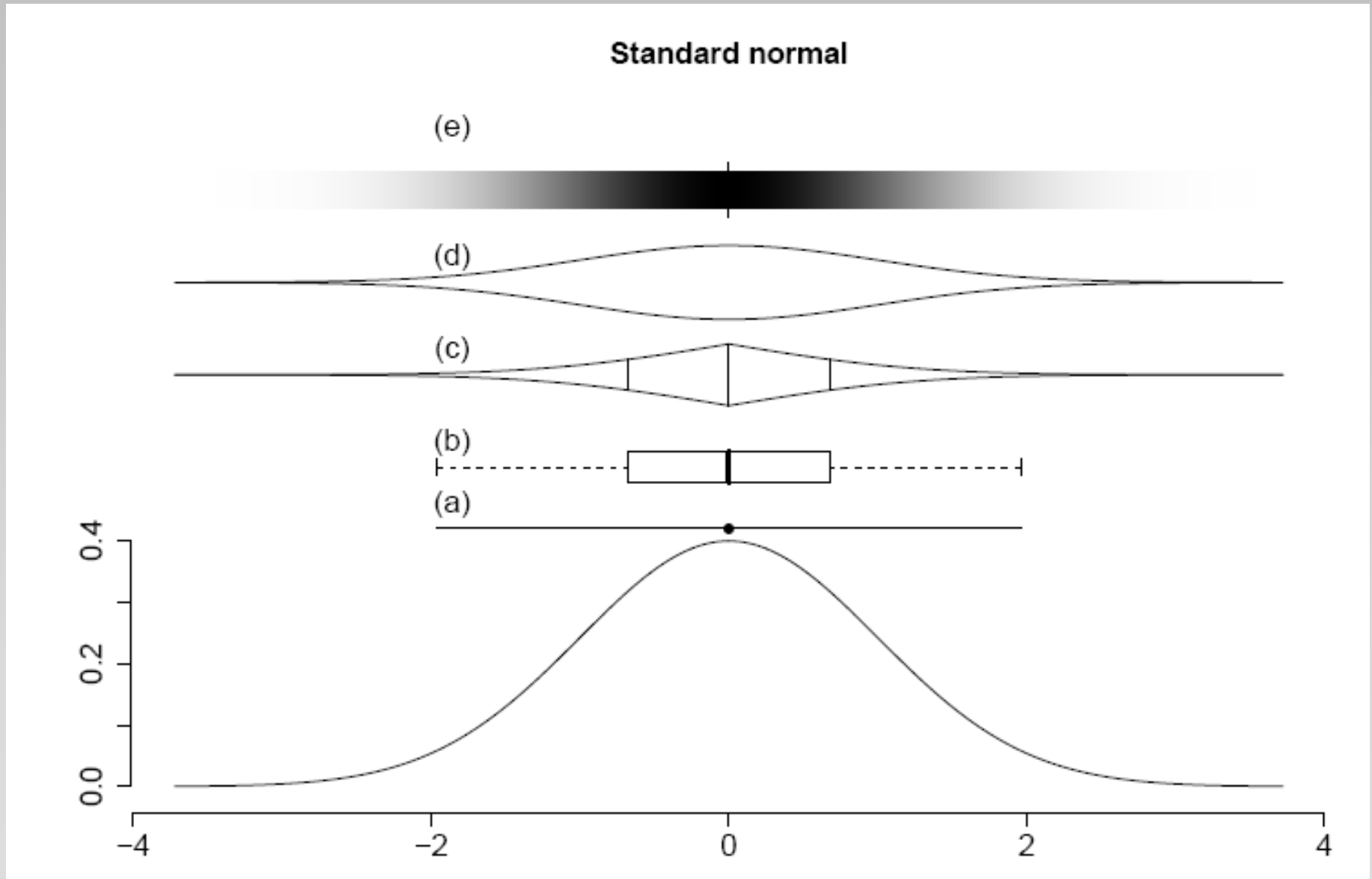
May 09

Bank of England 'fan charts'

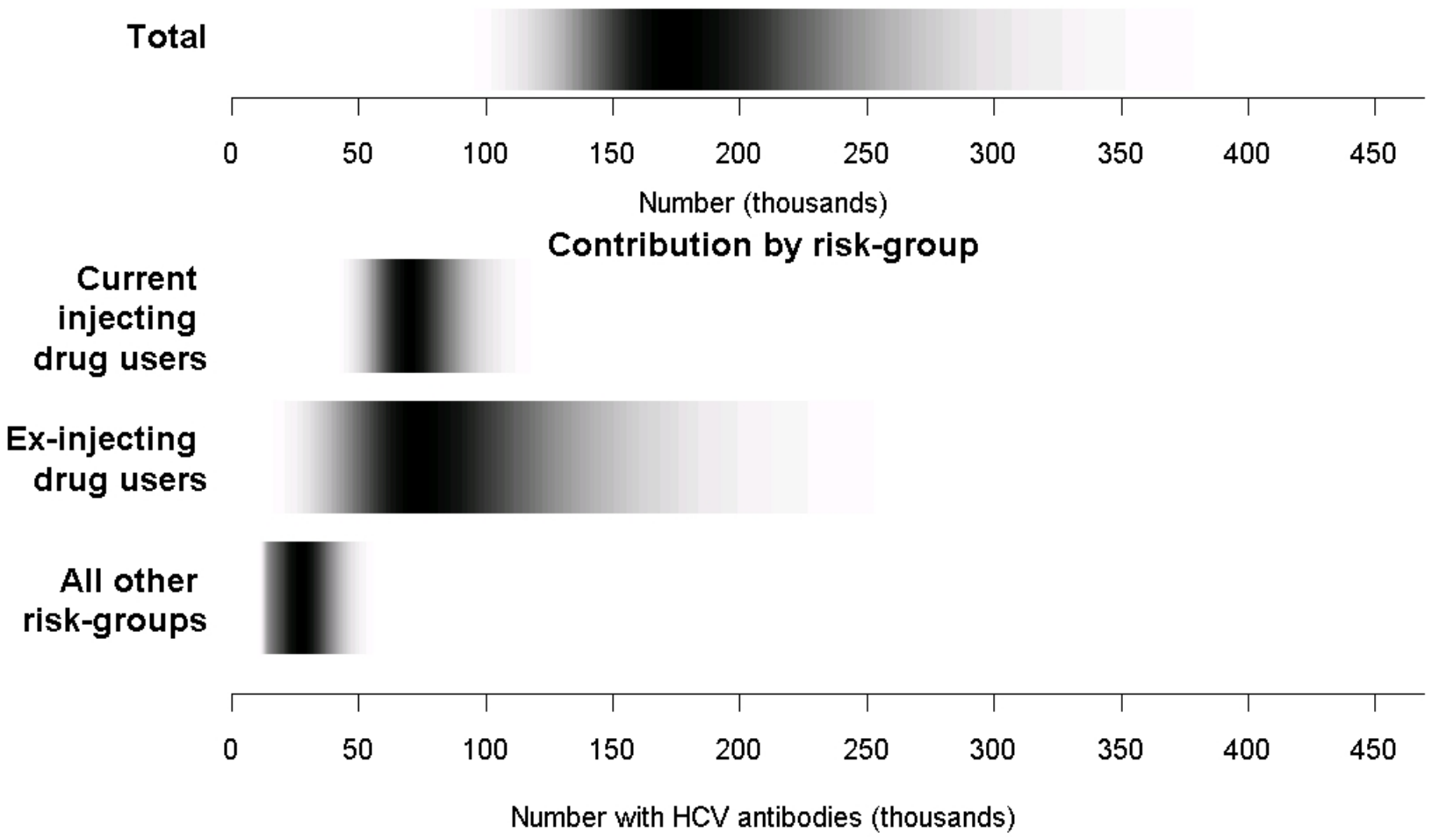


May 09

Chris Jackson's density strips



Hepatitis C prevalence in UK



70p
Saturday
May 30
1998
Published in London
and Manchester

Linda Grant in Weekend
in Saturday
in Travel

NEWSPAPER OF THE YEAR WEEKEND EDITION

The Guardian

29 children die and four brain-damaged in 53 operations ☐ Colleagues warned of dangers

Doctors ignored baby death toll

Parents denounce inquiry and claim compensation

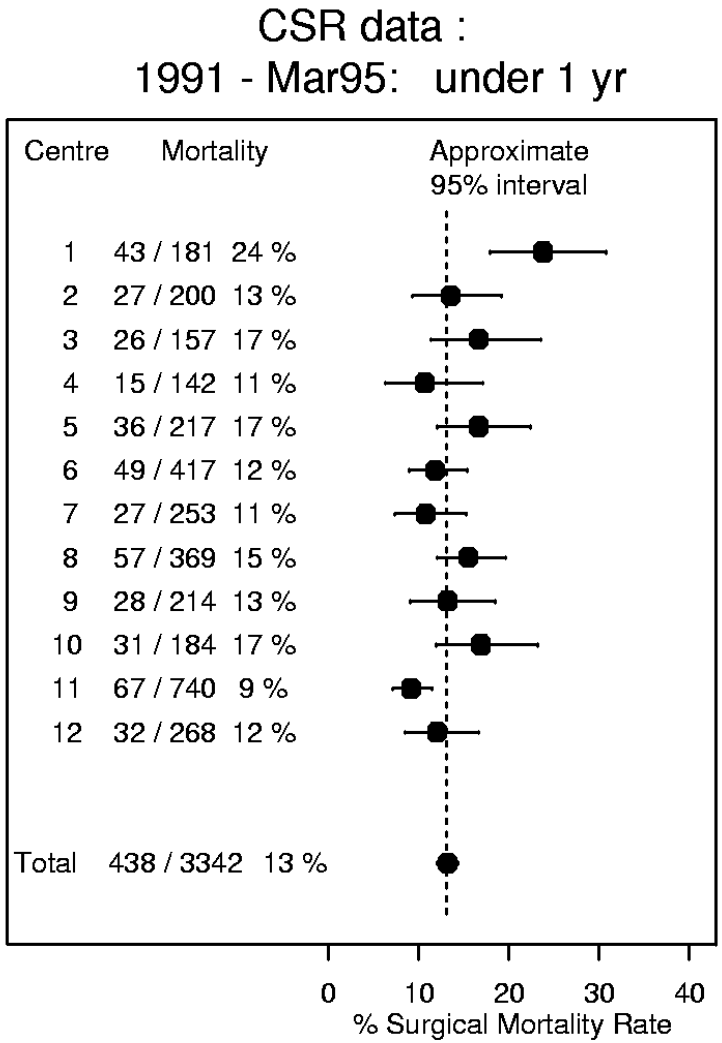
Sarah Boseley
Health Correspondent

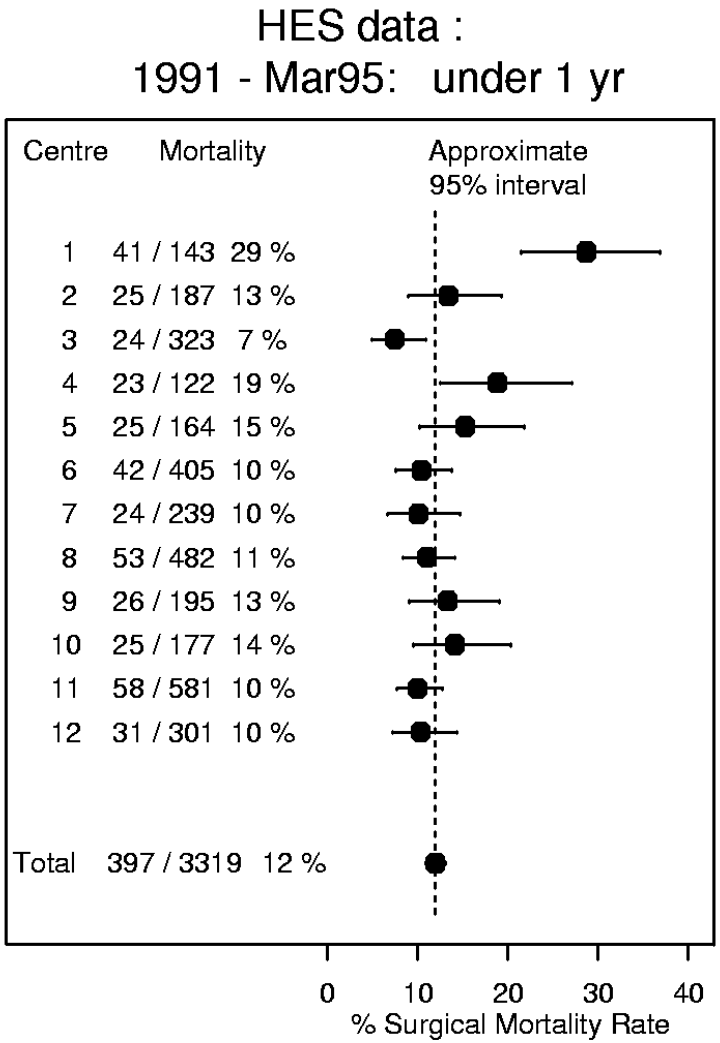
BRITAIN'S biggest ever medical disciplinary inquiry ended dramatically last night when three doctors were found to have risked babies' lives by continuing with heart operations even though their death rates were well above average.

The case has enormous consequences for the self-regulatee had examined "only the tip of the iceberg". Malcolm Curnow, one of the members of the Bristol Children's Heart Group, said he knew of 91 children who were dead or damaged. Only a public inquiry could uncover "the full horror story of injustice and betrayal imposed on parents and families".

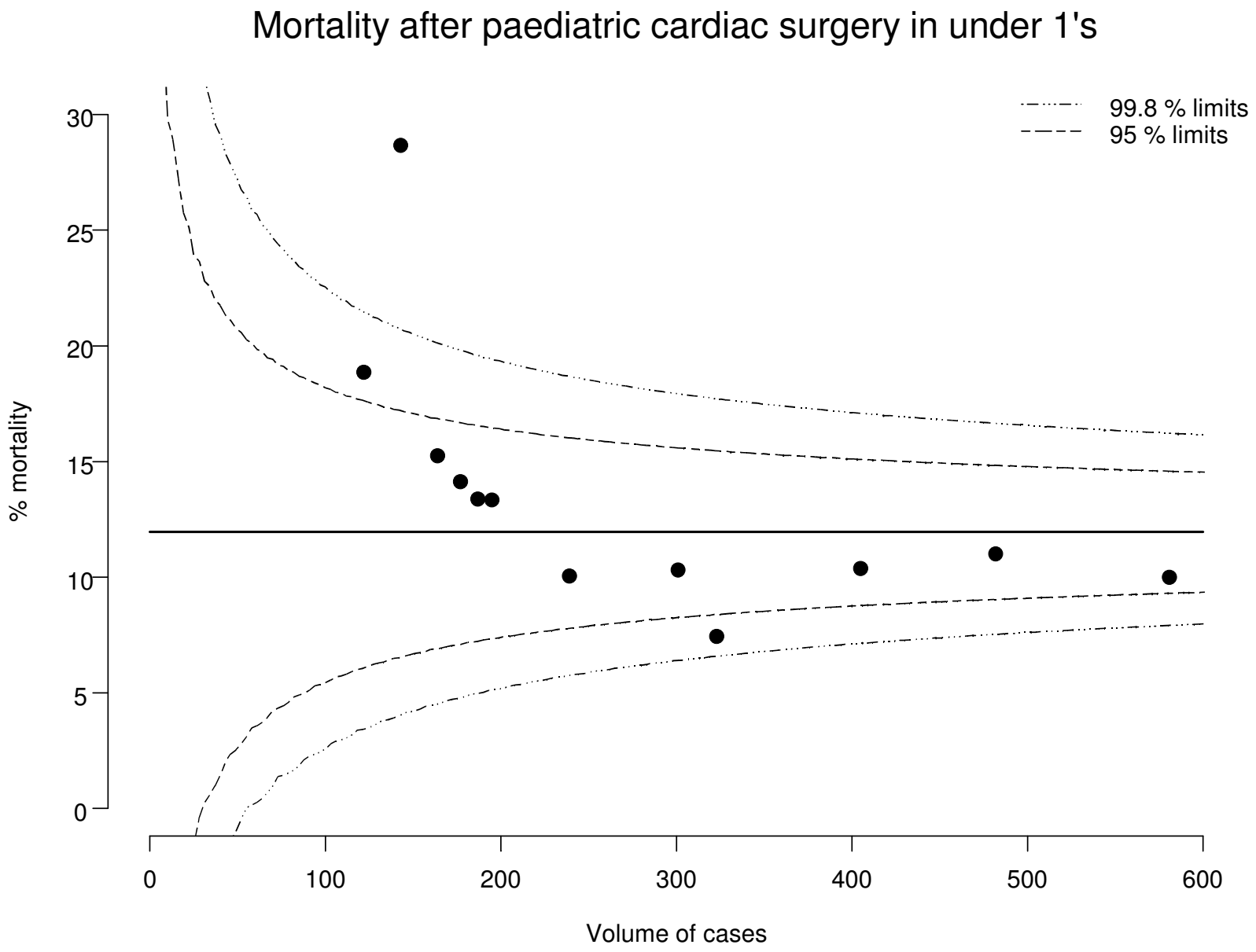
Acknowledging that justice needs to be seen to be done, Frank Dobson, the Health Secretary, has been discussing with the parents for weeks the scope of the independent inquiry he has prom-

Enlargement of results for under 1 year, 1991-Mar 1995





The Bristol Inquiry into excess mortality



UK Paediatric cardiac surgery website

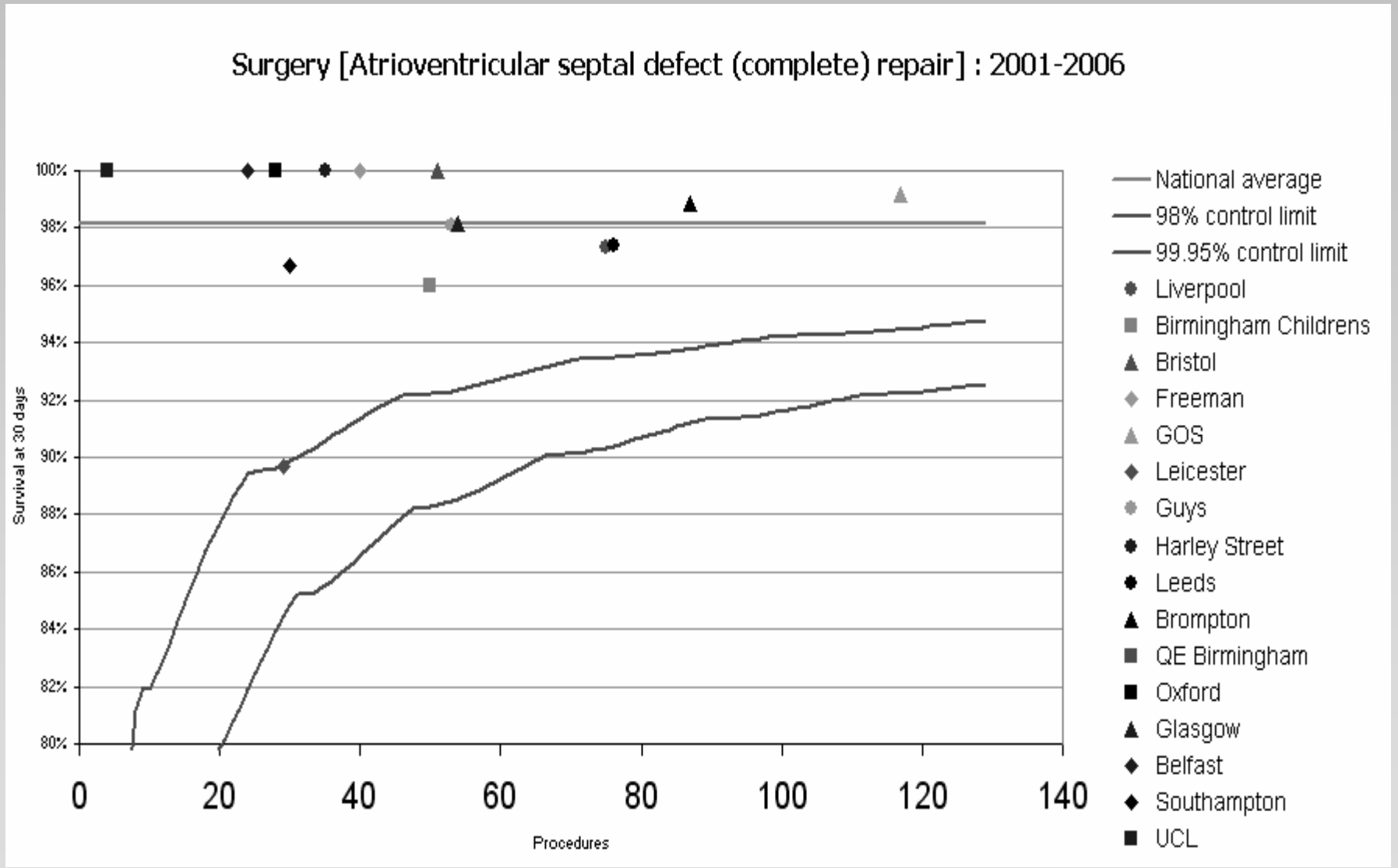
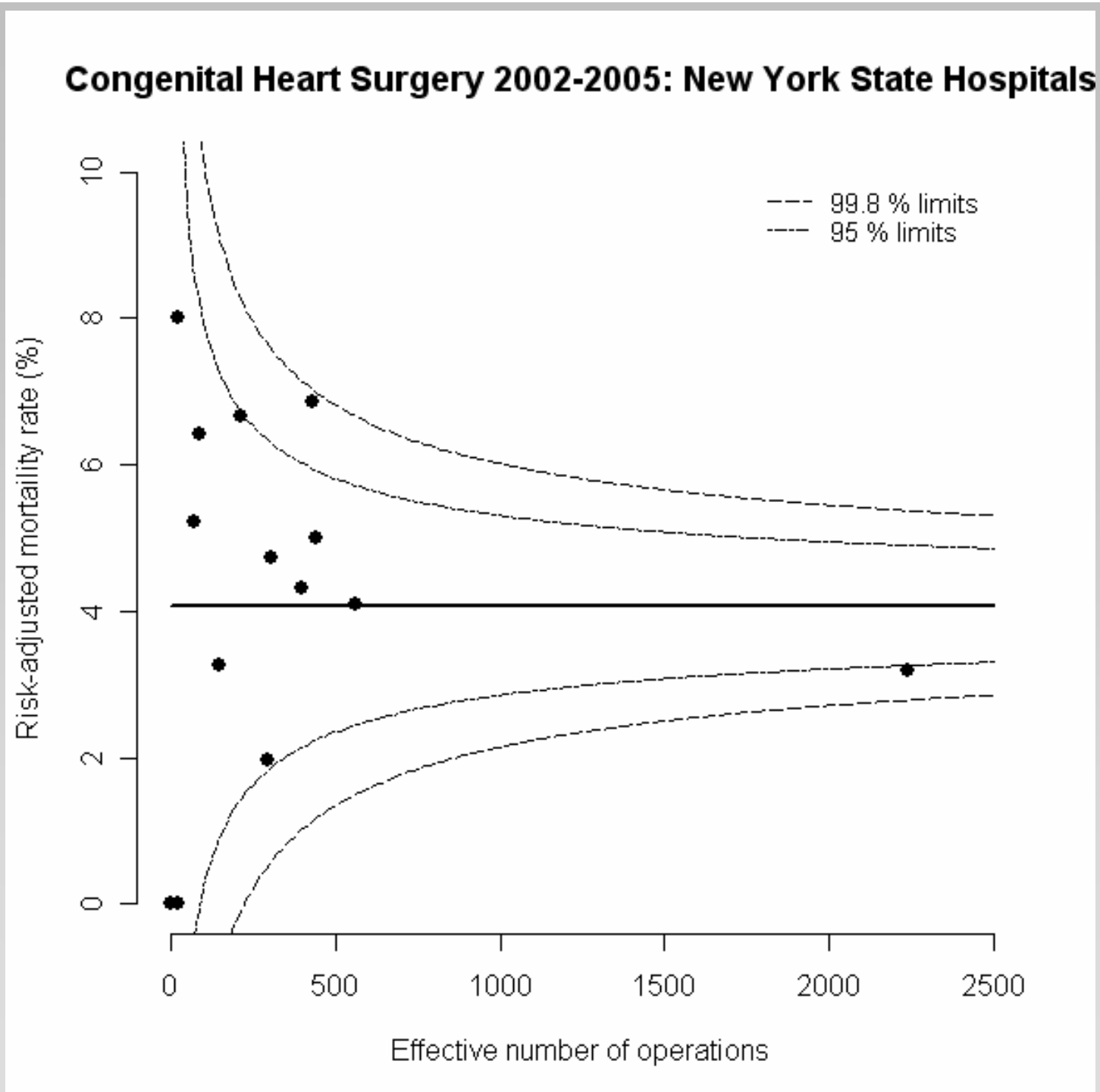


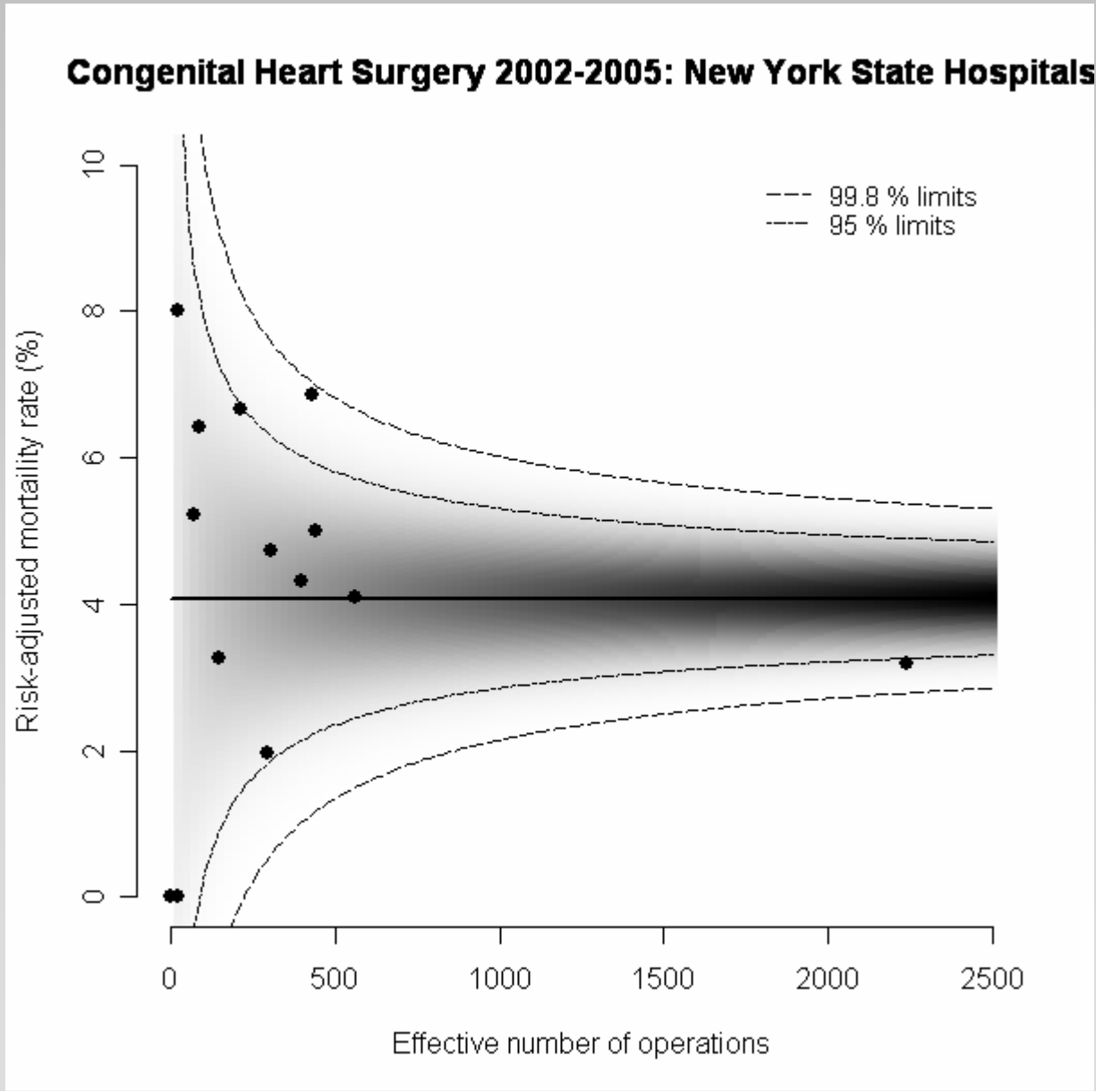
Table 1: Hospital Observed, Expected, and Risk-Adjusted Mortality Rates (RAMR) for Pediatric Congenital Cardiac Surgery in New York State, 2002-2005 Discharges (Listed Alphabetically by Hospital)

Hospital	Cases	Deaths	OMR	EMR	RAMR	95% CI for RAMR
Albany Medical Center	315	6	1.90	3.96	1.96	(0.72, 4.27)
Bellevue	14	0	0.00	0.44	0.00	(0.00,100.0)
Children's - Buffalo	12	0	0.00	7.91	0.00	(0.00,15.77)
Columbia Presbyterian-NYP	1807	74	4.10	5.26	3.18 **	(2.49, 3.99)
LIJ Medical Center	670	31	4.63	2.75	6.86 *	(4.66, 9.74)
Montefiore - Moses	170	6	3.53	2.24	6.43	(2.35,14.00)
Mount Sinai Hospital	550	23	4.18	3.40	5.01	(3.18, 7.52)
NYU Hospitals Center	326	15	4.60	2.81	6.67	(3.73,11.01)
North Shore Univ Hosp.	41	2	4.88	2.48	8.02	(0.90,28.96)
St. Francis Hosp.	7	0	0.00	0.39	0.00	(0.00,100.0)
Strong Memorial Hospital	533	24	4.50	4.50	4.09	(2.62, 6.08)
Univ. Hosp. - Stony Brook	201	4	1.99	1.55	5.22	(1.41,13.37)
Univ. Hosp. - Upstate	345	18	5.22	4.93	4.32	(2.56, 6.82)
Weill Cornell-NYP	237	5	2.11	2.64	3.27	(1.05, 7.62)
Westchester Medical Center	238	15	6.30	5.43	4.74	(2.65, 7.82)
Total	**5466**	**223**	**4.08**			

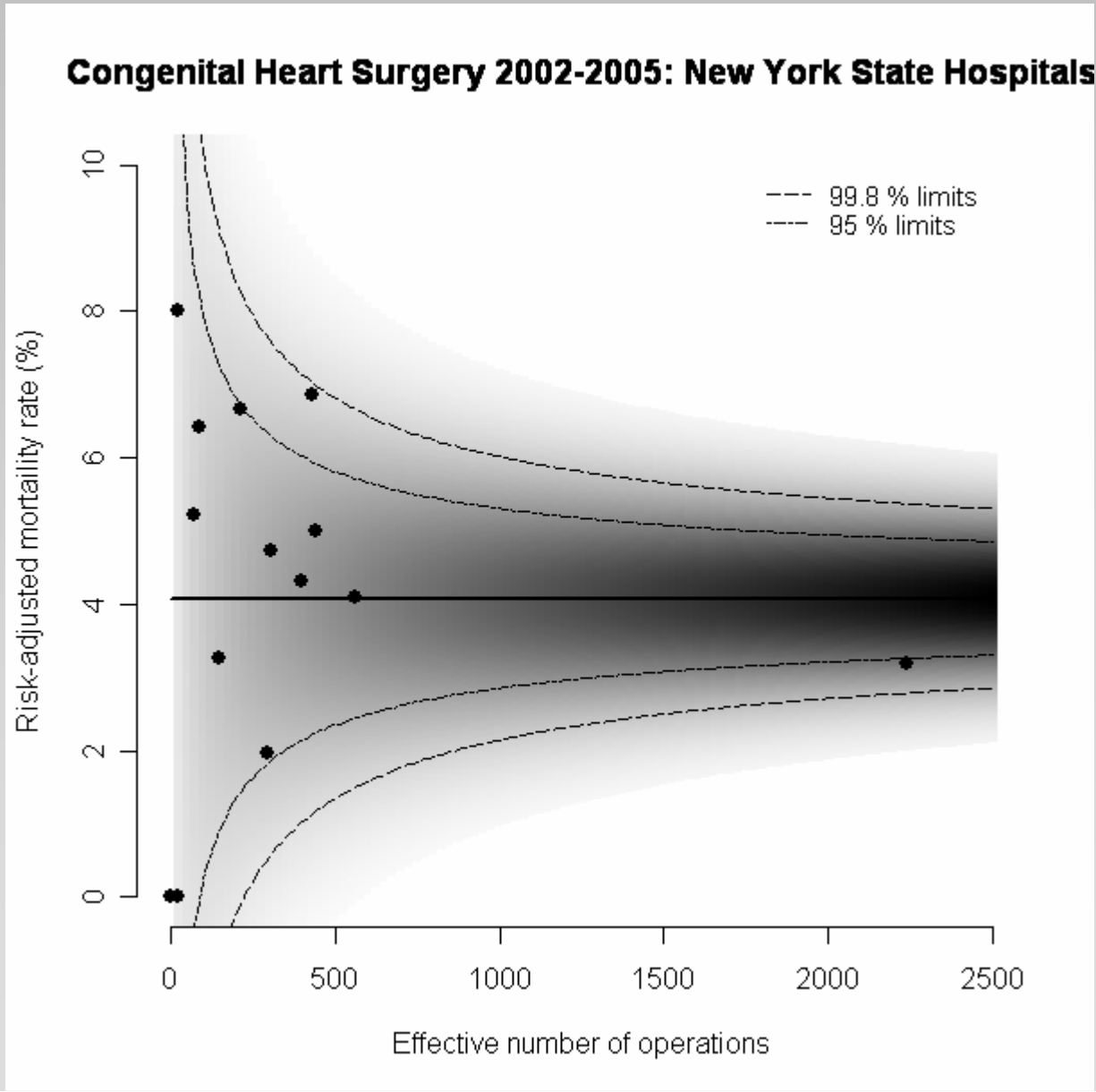
* Risk-adjusted mortality rate significantly higher than statewide rate based on 95 percent confidence interval.
** Risk-adjusted mortality rate significantly lower than statewide rate based on 95 percent confidence interval.


Congenital Heart Surgery 2002-2005: New York State Hospitals
99.8 % limits
95 % limits
Risk-adjusted mortality rate (%)
0
2
4
6
8
10
0
500
1000
1500
2000
2500
Effective number of operations

Funnels using density strips



Funnels using density strips^1/4



Visualising uncertain quantities

Extensive study in cartography

- Integrated symbols
- Split displays
- Toggled displays

Personal preferences

- Blurring
- Movement

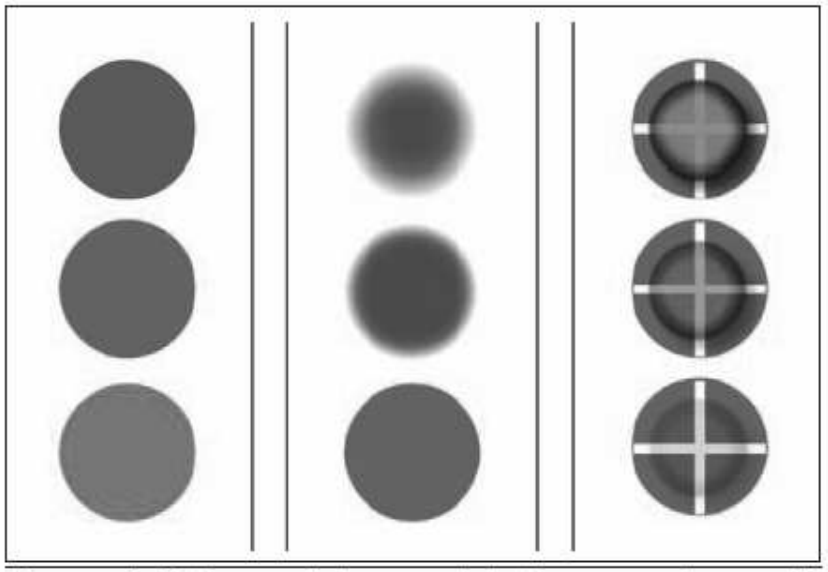


Figure 4. Point symbol sets depicting uncertainty with variation in (a) saturation, i.e., colors vary from saturated green, bottom, to unsaturated—top; (b) crispness of symbol edge—middle; and (c) transparency of symbol—right. In (c), transparency is applied to the smaller symbol in the foreground.

Hans Rosling

- Started *Gapminder* project for display of international public health information
- Employed son (video-game programmer)
- Flash animations using morphing for change over time
- Son now works for Google

Lie detectors

- A terrorist hides in a room with 99 innocent people
- You have a lie detector that is 95% accurate
- You get people out one at a time and ask them if they are a terrorist
- They all say no
- Eventually the machine goes ‘ping!’
- What is the chance that you have caught the terrorist?
- (a) 95% (b) 84% (c) 50% (d) 16% (e) 5%