

Index

- accountancy 210–11
- Addition Law 2, 22
- affect heuristic 51–2
- aggregate (frequency) judgements 79
- aggregation 92
 - Bayesian 180–1, 185
 - supra-Bayesian method of 180–90
- agriculture *see also* behavioural aggregation and mathematical aggregation 207–8
- AIDS 198
- aleatory uncertainty 10, 67, 119,
Glossary 227
- analytic hierarchy process (AHP) method 104
- anchoring-and-adjustment 39, 47–9,
Glossary 227
- anchoring effects 48–9
- APACHE II illness severity index 75
- archaeology 216
- arithmetic mean *see* mean
- association *Glossary* 227
 - eliciting 108–11
- attention/concentration (AC) 141
- audit 210–11
- availability 39–41, *Glossary* 228
 - bias attributed to 46–7
- base-rate effect (base-rate neglect) 43–4, *Glossary* 228
- Bayes linear approach 157
- Bayes' theorem 8–9, 38, 46, 200,
Glossary 228
- Bayesian hierarchical model 108,
Glossary 242
- Bayesian inference 157
- Bayesian methods 180–1, 199–200,
212
- Bayesian networks 196
- Bayesian probability revision 38
- Bayesian reasoning *Glossary* 228
- Bayesian statistics 9, 116, 134–5, 150,
201–2 *Glossary* 228
- BEEP (Bayesian Elicitation of Experts' Probabilities) project xi
- behavioural aggregation 25, 179,
186–9, *Glossary* 229
 - miscellaneous methods 188–9
 - performance 190
 - vs. mathematical aggregation 190–1
- behavioural decision-making 34, 38
- Bernoulli distribution 125,
Glossary 229
- Bernoulli trials/Bernoulli process 125,
Glossary 229
- best practice, guidance on 217–22
- beta distribution 117, 125–6, 128, 131,
135–6, 159, *Glossary* 229
- beta probability density 129
- bets 88–90
- bias 35, 52, 104, *Glossary* 229
 - attributed to availability and representativeness 46–7
 - research programme 38–53
- bimodal *Glossary* 229
- binomial distribution 125, 137
- body mass index (BMI) 198
- business domain, calibration 72
- business studies 209–12, 215

- calibration 171–6
 - automatic 162–3
 - good 72, 74, 162
 - key lessons from literature 82
 - of subjective probabilities 62–82, *Glossary* 229
 - poor 74, 77
 - theories of 79–82
- calibration curve 63–5
- calibration performance 74
 - feedback 70
- calibration research 67–8
 - applied settings 72–4
 - general findings 68–71
- case studies 193–216
- Cattle Disease Diagnosis System 206
- central tendency measures (or central tendency parameter) *Glossary* 229
- classical statistics *see* frequentist statistics
- climate change 212–13
- closeness, measure of 171
- coefficient of variation *Glossary* 232
- cognitive capabilities 35–6
- cognitive continuum theory 56
- cognitive factors *Glossary* 232
- cognitive science approach 53–4
- coherent/coherence 21–2, 171–6, *Glossary* 232
- conditional distribution 7, *Glossary* 232
- conditional independence *Glossary* 232
- conditional probability 44, 111–12, *Glossary* 232
- conditioning 194
- confusion of the inverse 44–5, *Glossary* 232
- conjugate distribution 125, 140
- conjugate prior *Glossary* 232
- conjunction fallacy 42–3, 57, *Glossary* 233
- conjunctive (and disjunctive)
 - propositions *Glossary* 233
- conservation 214
- conservatism *Glossary* 233
- constructive processes 36
- continuous probability distributions, scoring rules 169–71
- continuous random variables 4, *Glossary* 233
 - independent 7
- contrast effect 15–16
- Cooke’s weighting method 184–5
- copula *Glossary* 233
- corrective procedures 70–1
- correlation coefficient/coefficient matrix 8, *Glossary* 234
- covariance/covariance matrix 140, *Glossary* 234, *Glossary* 255
- credible interval/credible region *Glossary* 234–5
- cue-criterion relationships 70
- cues and cue weighting 144, *Glossary* 235
- cumulative distribution function (CDF) 98–102, 127–9, 132–5, *Glossary* 235
- debiasing 89–95
 - general principles for judgement 90–1
 - methods according to underlying assumption 90
- decision maker 115, 181, 185, *Glossary* 235
 - role of 28
 - supra-Bayesian 180
- decision making *Glossary* 235
- decision strategy 55
- decision theory *Glossary* 235–7
- decomposition 168
- default Bayesian methods *see* objective Bayesians
- degree of belief 11–12
- degrees of freedom 122
- delayed memory (DM) 141
- Delphi method 189, *Glossary* 237
- demography 216
- Dempster–Shafer theory *Glossary* 237–8
- density, symmetric 4
- density function 158–9
 - unimodal 4
 - see also* probability density function (pdf)
- design of experiments 9

- difference threshold 15
 Dirichlet distribution 137, 139, 175
 discrete probability distribution, scoring rules 165–9
 discrete random variable *Glossary* 238
 discrimination 63, 65–6
 distribution function 3
 see also cumulative distribution function (CDF)
 distributions 113–14
 eliciting 97–119, 153–60, 219–21, 224–5
 from probabilities to 97–100
 multivariate 107–14
 research questions 119
 summaries of 5–7
 tails of 103
 univariate 100–7
 Dutch book *Glossary* 238

 ecological plus error theories 81
 ecological theories 80
 ecology 214
 economics 209–12, 215
 elicitation 5, 9
 and psychology of judgement 14–20
 background and preparation 28–9
 choice of format 25–6
 components of 27–8
 context 25–31, 217, 223
 conventions 31
 decomposition 30–1
 direct estimation 22, 87
 evaluating 161–77, 221–2, 225
 examples 10
 expert opinion, published examples 193–216
 formats for responses 87–9
 four-stage method 27
 good 161
 group 186–9
 implications for 14, 16–17, 20
 interview vs. questionnaire 25–6
 iterative process 31
 literature 27, 163
 model 28–31
 planning 25
 prior information 9
 probabilities 61–96
 process of 27–31
 purpose 9, 23
 representation and methods 82–9
 research questions 177
 response scales 87–8
 roles in 28
 statistical contexts 9
 structuring 30–1
 techniques 123
 use of term 14
 elicitation error, quantifying 114–15
 elicitation interview, example 193–5
 Ellsberg Paradox 88
 emergency services 216
 empirical distribution 7
 encoding 194–5
 engine sales, eliciting 193–5
 engineering applications 215
 environment 214, *Glossary* 238–9
 environmental health 212–13
 epistemic uncertainty 10, 13, 119, *Glossary* 239
 epsilon-contamination class 116
 equivalent prior sample (EPS) method 125, 129–30, 211, *Glossary* 239
 error *Glossary* 239
 occurrence rate, auditors 211
 theories 81
 estuarine clam (*Macoma balthica*) 213
 event types 68
 EXCALIBR software 206
 expectation (expected value) *Glossary* 239
 expected utility *see* utility
 expert opinion, published examples of elicitation of 193–216
 expert system *Glossary* 240
 middle way 54–5
 experts 52–5, *Glossary* 239
 competence 55
 criteria for 29
 identify and recruit 29
 motivating 29–30
 one or more 25
 training 29–30
 use of term 26–7

- experts (*continued*)
 - vs. the rest 37–8
 - see also* multiple experts
- explicit disjunction 50
- extending the argument 113
- extensional reasoning *Glossary* 240
- external approach 115
- externally Bayesian approach 182

- facilitator 28, *Glossary* 240
- feedback 70, 77, 116–18, 157, 173–6
- feedforward 165
- finance 209–12, 215
- financial forecasts 212
- first-order autoregressive (AR(1)) time series model 148
- fitted density function 99
- fitting 100, 121–51, 220–1, 225, *Glossary* 240
- fixed stopping 38
- forecasting
 - outcomes 71
 - performance 73
- forest ecosystems 212–13
- frequency formats 46
- frequency probability 11–12, *Glossary* 240
- frequency representations 46–7
- frequentist statistics 13, *Glossary* 240–1
- frequentist theory 13
- full-range tasks 67
- Fuzzy Set Theory *Glossary* 241

- Game Theory 216
- gamma distribution *Glossary* 241–2
- general memory (GM) 141
- generalised linear models (GLMs), eliciting opinion about parameters 145–6
- geometric mean 182, *Glossary* 242
- good performance 55
- graphical feedback 175
- graphical models *Glossary* 242
 - see also* Bayesian networks
- group polarisation 187–8
- guidance on best practice 217–22

- half-range tasks 67–9
- healthcare improvement projects 209
- heuristics 35, 47–8, 51–2, 62, 73, *Glossary* 242
 - research programme 38–53
- hindsight bias 70
- histogram *Glossary* 242–3
 - distribution 135–6
 - technique 134
- human information processing 35–6
- hyperparameters *see* parameters
- hypothetical future sample (HFS)
 - method 125, 127, 129, 137–8, *Glossary* 243

- ignorance, probabilistic representation 23
- implicit disjunction 50
- implicit hypothesis 50
- imprecision 114–18, 153–60, 221
 - eliciting distributions 225
 - research questions 160
- inaccurate knowledge 161–2
- inappropriate inference 44
- incomplete information 156–9
- independence *Glossary* 243
- individual probabilities 5
- information component 185
- inside view vs. outside view 56–7
- interactive computer program 175
- interactive graphical method 147
- internal approach 115
- interquartile range (IQR) 210
- interval coverage probability 103
- intervals 6
- intuitive reasoning *Glossary* 243
- iterative process 31

- joint distributions 7–8
 - see also* multivariate distribution
- joint probability 111–12
 - see also* multivariate distribution
- judgement
 - absolute or relative? 15–18
 - accountability 71
 - and decision-making 34
 - applications 20–3
 - as form of perception 18
 - flawed 36

- fundamentals 1–24, 217, 223
 meta-theories 55–8
 probability 17
 psychology of 14–20, 218–19,
 223–4
 under uncertainty 33–59
 research 37–8
 just noticeable difference (JND) 15

 Kendall's tau *Glossary* 243
 kurtosis 6
 see also tails of distribution

 law 215
 law of large numbers *Glossary* 243–4
 law of small numbers 44, *Glossary* 244
 least informative method 131
 lens model *Glossary* 244–5
 likelihood function *Glossary* 246
 likelihood ratios 209
 linear opinion pool 181, 184
 linear regression model, eliciting
 opinion about parameters 142–5
 linear scoring rule 164
 location measure 6, *Glossary* 246
 location parameter *Glossary* 246
 log-likelihood function *Glossary* 246
 log-linear models 145
 logarithmic opinion pool 182–3
 logarithmic scoring rule 168, 170

 main effects *Glossary* 246
 maps, probabilities of pixel
 classification 216
 marginal distributions 149
 marginalisation 182
 Markov Chain Monte Carlo (MCMC)
 methods 145, 150, 170, 213, 215,
 Glossary 246
 mathematical aggregation 25, 179–86,
 Glossary 246
 performance 185–6
 vs. behavioural aggregation 190–1
 maximise (minimise) a function
 Glossary 247
 maximum likelihood estimate (MLE)
 206
 mean *Glossary* 247
 mean absolute deviation *Glossary* 247

 mean probability score 166
 mean squared deviation *see* variance
 meaning, reconstruction 20
 measures of correlation 7–8
 measures of scale or dispersion 6
 measures of shape 6
 measures of skewness 6
 mechanistic aggregation *see*
 mathematical aggregation
 mechanistic model *Glossary* 247
 median *Glossary* 247
 medicine
 calibration research 74–7
 clinical depression 203
 clinical judgement making 203
 clinical psychology 202–3
 clinical trials 199–201
 diagnosis and treatment decisions
 195–9, 213–14
 examples of elicitation 195–204
 intensive care units (ICUs)
 202
 management of severe head injuries
 199
 obsessive compulsive (OC)
 symptoms 203
 operative mortality 199
 radioactive iodine (RAI) treatment
 201
 survival analysis 201–2
 systolic blood pressure (SBP) after
 open-heart surgery 200
 memory 19–20
 associations 19
 meteorology 208–9
 forecasting 72
 mode 6, *Glossary* 247–8
 monotone or monotonic (monotonicity)
 Glossary 248
 Monte Carlo Markov Chain (MCMC)
 see Markov Chain Monte Carlo
 (MCMC) methods
 most informative method 131
 motivating 194
 multi-location auditing 211
 multinomial distribution 137
 multiple experts 179–92, 222, 226
 elicitation practice 191

- multiple experts (*continued*)
 - overview 179
 - research questions 191–2
- Multiplication Law 7, 22
- Multivariate distribution 111–4, 119, 123–4 *Glossary* 248
- Multivariate normal (MVN) distribution 148
 - eliciting opinion about parameters of 139–42 *Glossary* 248
- Multivariate sampling models 150
- Murphy’s decomposition 166, 168
- mutually exclusive, use of term 2

- naive intuitive statistician metaphor 58
- natural assessments 39
- Neuse estuary 213
- noise, managing 91–2
- Nominal Group Technique 189
- non-informative priors 200
- non-negative definite *see*
 - positive-definite
- non-parametric model *Glossary* 250
- normal distribution 4–5, *Glossary* 250
 - family of 122
- normalisation *Glossary* 250
- normative expertise 69, *Glossary* 250–1
- normative theories of probability 21
- nuclear industry 204–5
 - risk assessment 205
 - rupture probabilities 205
- nuclear power plants, probability safety assessments (PSAs) 204
- nuclear waste 204
- numerical integration 132

- objective accuracy 173
- objective and subjective Bayesians *Glossary* 251
- objective distributions 207
- observables *Glossary* 252
- oceanography 213
- ophthalmology 216
- opinion pool 181–4, *Glossary* 252
- optimal decision *Glossary* 252
- optional stopping 38
- orthogonal *Glossary* 252

- outside view 56–7
- overconfidence 63–4, 68–70, 103–4, 203, *Glossary* 252–3
- overestimation 78
- over-extremity 63, 65, 68
- overfitting 116–18, 173–6, *Glossary* 253

- parameters (hyperparameters) 13, *Glossary* 253–4
- parametric distribution *Glossary* 254
 - deficiencies in existing research 149–50
 - eliciting and fitting 121–51, 220–1, 225
 - research questions 151
- Pareto distribution *Glossary* 254
- Pearson correlation coefficient 8
- percentile *Glossary* 254
- perceptual organisation (PO) 141
- personal probability 11–13
 - see also* subjective probability
- PERT (program evaluation and review technique) 136
- physical magnitudes 15
- piecewise-linear model 146
- Poisson distribution 147
- Poisson regression 145
- polynomial regression 144
- poor discrimination 66
- poor performance 55
- positive semi-definite *see*
 - positive-definite
- positive-definite *Glossary* 255
- post hoc corrections 94–5
- posterior distribution 145, 159, *Glossary* 256
- posterior mean 158–9
- posterior probability 8
- prior distribution 22–3, 137, 140, 144–5, 147–9, 154, 180, *Glossary* 256
 - class *G* 116
- prior probability 8
 - under-weighting 43–4
- probability *Glossary* 256
 - assessment 104–5
 - incoherence of 42–3

- complex example 2–3
 elicitation 24, 61–96, 219, 224
 extended example 12–14
 fundamentals 1–24, 217, 223
 imprecise 153
 interpretation 10–14, 22–3
 normative theories 21
 numerical expression 83–5
 research questions 24, 95
 recomposition 71
 summaries based on 100–4
 symbol 2
 theoretical study 2
 training 30
 true 23
 use of term 1–3
 values 1–2
 probability assessment, coherent
 172
 probability density function (pdf) 4,
 126–7, 132, 146, *Glossary* 256
 probability distribution 3–5
 family of 121–2
 structure 121
 true 23
 probability judgements 17, 153
 calibration 68–70, 77–9
 case study 74–7
 physicians' 74–7
 recomposition 71
 probability mass function (pmf) 3–4,
 Glossary 256–7
 probability safety assessments (PSA)
 for nuclear power plants 204
 probability score (PS) 166
 probability scoring rule 166
 probability statements 102
 probability wheel 88–9,
 Glossary 257
 proper scoring rule 170–1
 proportions
 eliciting opinion 124–32
 set of 137–9
 prospect theory *Glossary* 257
 Prospective Investigation of Pulmonary
 Embolism Diagnosis (PIOPED)
 198–9
 pruning bias 48
 pruning effects 49
 psychology 15, 202–3, 215
 role in elicitation 33–4
 see also medicine; uncertainty
 psychology of judgement under
 uncertainty 14–20, 35–59,
 218–19, 223–4
 Psychology of Judgement under
 Uncertainty 218–19, 223–4
 psychophysical law 15
 psychophysical magnitudes 15
 psychophysics 15, 18
 public health 212–13
 pulmonary embolism (PE) 198

 quadratic scoring rule 166
 quantiles 5–6, 100, *Glossary* 257
 quartiles 147, *Glossary* 257

 random variables 3–5
 range-frequency compromise 18
 ranked probability score 169–70
 receiver operating characteristic (ROC)
 curves 197–8
 regression 112–13
 regression coefficient 142
 regressiveness, insufficient in
 prediction 45, 92–4
 reliability curves 208
 repeatable event *Glossary* 257–8
 representativeness 39, 41–5, *Glossary*
 258
 bias attributed to 46–7
 reduced to similarity 41–2
 research areas 23–6
 response modes 67
 response scales 87–8
 risk factors for surgery 77
 robust Bayesian methods *Glossary* 258

 sample size, insensitivity to 44
 scalar quantity, eliciting opinion 132–7
 scale parameter *Glossary* 258
 scores, uses of 165
 scoring rules 63, 163–71, *Glossary* 258
 applications 164–5
 continuous probability distributions
 169–71
 criticism of 169

- scoring rules (*continued*)
 - development 165
 - discrete probability distributions 165–9
 - effective 171
 - improper 164
 - notation 165
 - proper 164, 169
 - purposes of 164
 - spherical 168
 - use of term 164
- sensitivity analysis 115–16, *Glossary* 259
- similarity 41–2
- single-case probability judgements 79
- single variable distribution
 - bounded 123
 - positive 123
 - unrestricted 123
- skew or skewed distribution 6, *Glossary* 259
- smooth function (rough function) *Glossary* 259
- spherical scoring rule 168
- sport 215
- stage models 80
- standard deviation 6
 - see also* variance
- statistical model *Glossary* 260
- statistical summary *Glossary* 260–1
- statistician, role of 28
- stock forecasting 73–4
- stock market values 72–3
- strength and weight model 80
- structuring 107–8, 194
- student *t* distribution *see t* distribution
- subadditive assessments 50
- subjective Bayesians *see* objective and subjective Bayesians
- subjective distribution 138, 141, 170, 207
- subjective probability 11, 197–8, 204, 210, *Glossary* 261
 - calibration 62–82
 - conservatism in revision 38
 - examples of elicitation 213–16
 - research 38
 - theories of calibration 79–82
- substantive expert 69, *Glossary* 261
 - role of 28
- summaries 99, 105–7
 - based on probabilities 100–4
 - of distributions 5–7
 - see also* statistic summary
- support theory 49–51, 80, *Glossary* 261
- supra-Bayesian decision maker 180
- supra-Bayesian method of aggregation 181
- symmetric matrix *Glossary* 255
- t* distribution *Glossary* 262
 - spread 141
- tails of distribution 103, *Glossary* 262
- tertiles 6
- transitive ranking *Glossary* 262
- triangular distribution 132, *Glossary* 262–3
- two-alternative forced choice (2AFC) paradigm 67
- uncertainty 3, 6, 10–14, 67, 69, 114–18, 153–60, 221
 - eliciting distributions 225
 - eliciting practice 58–9, 160
 - map between numerical probability and verbal descriptions 205
 - modes for representing 83–7
 - psychology of 218–19, 223–4
 - psychology of judgement under 33–59
 - research questions 59, 160
 - verbal expressions of 85–7
- underconfidence 63–4, 69, 212
- uniform distribution *Glossary* 263
- unimodal *Glossary* 263
- unit root problem 148
- unpacking principle 50
- utility *Glossary* 263–4
- vague prior *Glossary* 264
- value biasing 76, 78
- value judgements 78
- variable interval method 133, 211
- variance 6, *Glossary* 264
 - meaning of 106

- variance-covariance matrix 140–1
 - see also* covariance matrix
- verbal comprehension (VC) 141
- verifying 195
- veterinary science 206–7, 214–15
 - contagious animal diseases 206–7
- visual feedback 175
- visual linear scale (VLS) 198–9
- Von Mises-Jenkinson distribution 148
- weather conditions, modelling 209
- weather forecasters, performance of 208–9
- Weber–Fechner law 15
- Wechsler Adult Intelligence Scale-revised test 141
- Wechsler Memory Scale-revised test 141
- weighted average *Glossary* 265