

Measurement theory and practice

The world through quantification

David J. Hand

 **WILEY**
wiley.com

Contents

<i>Preface</i>	<i>ix</i>
<i>Acknowledgements</i>	<i>xi</i>
1 Introduction	1
1.1 The need	1
1.2 The origins	6
1.2.1 The origins of numbers	6
1.2.2 The origins of measurement	9
1.3 But is it measurement?	12
1.4 Measurement and statistics	19
1.5 Against measurement	21
1.6 And more	23
1.7 This book	24
2 The nature of measurement	25
2.1 Introduction	25
2.2 Representational measurement	27
2.2.1 Axiom systems	32
2.2.2 Order relationships	33
2.2.3 Additive relationships	35
2.2.4 Conjoint measurement	36
2.2.5 Uniqueness of representational measurement mappings	40
2.2.6 Alternative numerical relationships	43
2.2.7 Representing different empirical relationships	44
2.2.8 ‘Classical’ measurement	49
2.3 Pragmatic measurement	52
2.4 Measurement and statistics	60
2.4.1 Meaningfulness	60
2.4.2 Alternative measurement scales	68
2.4.3 Transformations and statistics	69
2.4.4 Measuring change	71
2.5 Measurement, statistics and meaningfulness: a twentieth-century controversy	72
2.6 Parametric versus nonparametric statistics	82

3	The process of measurement	84
3.1	Introduction	84
3.2	Direct scaling	85
3.3	Indirect scaling	87
3.3.1	Thurstone scales	90
3.3.2	Likert scales	91
3.3.3	Guttman scaling	91
3.3.4	Coombs scaling	96
3.3.5	The Bradley–Terry model	98
3.4	Modern unidimensional scaling methods	99
3.5	Latent variable approaches to indirect models	103
3.5.1	The basic model	103
3.5.2	Factor analysis	107
3.5.3	Poisson models	109
3.5.4	Binary responses	111
3.6	More complicated models	115
3.7	Quantifying categorical scales	116
3.8	Item analysis	120
3.9	Multiple-choice questions	121
3.10	Conclusion	122
4	Accuracy of measurement	123
4.1	Introduction	123
4.2	Validity and reliability	129
4.2.1	Validity	131
4.2.2	Reliability	134
4.3	Inter-rater reliability	140
4.4	Other aspects of reliability	144
4.5	Squeezing the pips	145
5	Measurement in psychology	151
5.1	Introduction	151
5.2	Difficulties in psychological measurement	156
5.3	Measuring intelligence	160
5.3.1	The Stanford–Binet Intelligence Scale	162
5.3.2	The Wechsler Adult Intelligence Scale (WAIS)	163
5.4	Measuring personality	163
5.5	Clinical assessment	164
5.6	Psychophysics	165
5.7	Measuring strength of attitude and opinion	168
5.8	Actuarial versus clinical methods	169
5.9	Educational testing	175
5.9.1	Scholastic Assessment Tests	177
5.9.2	Grade inflation	177
5.10	Test equating	180

6	Measurement in medicine	182
6.1	Introduction	182
6.2	The origins of medical measurement	183
6.2.1	The individual level	183
6.2.2	The aggregate level	187
6.3	Direct measurement in medicine	187
6.4	Indirect measurement in medicine	189
6.5	Some examples of indirect medical measurement	191
6.5.1	Physical disability	191
6.5.2	Psychological health	192
6.5.3	Pain	194
6.5.4	Health-related quality of life	195
6.5.5	Measuring spinal deformity in osteoporosis	197
6.6	Measures of diagnostic accuracy	198
6.7	Measures to compare treatments	201
6.8	Conclusion	202
7	Measurement in the physical sciences	204
7.1	Dimensions in physics	204
7.1.1	The history	204
7.1.2	The theory	206
7.1.3	The practice	208
	7.1.3.1 <i>Finding the forms of equations</i>	209
	7.1.3.2 <i>Detecting errors</i>	211
	7.1.3.2.1 <i>Examples in mathematics</i>	211
	7.1.3.2.2 <i>Examples in statistics</i>	212
7.2	Units of measurement	215
7.2.1	Background	215
7.2.2	The Système International d'Unités	221
7.2.3	Length	222
7.2.4	Area	226
7.2.5	Volume and density	227
7.2.6	Weight	231
7.2.7	Pressure	234
7.2.8	Energy	234
7.2.9	Sound	235
7.2.10	Electrical and magnetic units	236
7.2.11	Time	238
7.2.12	Heat, temperature and entropy	241
7.2.13	Light and other kinds of radiation	244
7.2.14	Other measurable physical properties	245
7.2.15	Conclusion	247
8	Measurement in economics and the social sciences	248
8.1	Introduction	248
8.2	Performance indicators	251

8.2.1	League tables: an example	255
8.2.2	The Research Assessment Exercise	256
8.3	Economic indicators	257
8.4	Price indices	259
8.4.1	General	259
8.4.2	An example: the UK Retail Prices Index	267
8.5	The American Customer Satisfaction Index	268
8.6	Crime	269
8.7	Workload measurement	270
8.8	Conclusion	271
9	Measurement in other areas	272
9.1	Introduction	272
9.2	Measuring probability	272
9.3	Software metrics	275
9.4	Database management systems	276
9.5	Informetrics	277
9.5.1	Characterizing documents	277
9.5.2	Impact factors	278
9.6	And beyond	278
9.7	Conclusion	279
	<i>References</i>	281
	<i>Author index</i>	301
	<i>Subject index</i>	309