

## *Author Index*

- Ackerman, T. A., 295, 376  
 Agresti, A., 82, 376  
 Aitkin, M., 138, 377  
 Allen, N. L., 37, 379  
 Andrich, D., 127, 376  
 Angoff, W. H., 19, 25, 29, 376, 382
- Baker, F. B., 121, 136, 141, 376  
 Bandalos, D. L., 258–259, 272, 281, 376  
 Barton, M. A., 138, 387  
 Bejar, I. I., 129, 133, 376  
 Beland, S., 38, 382  
 Benjamini, Y., 15  
 Bentler, P. M., 259, 262–263, 272, 280–281,  
 284, 287, 354, 377–378, 380, 385  
 Birnbaum, A., 136, 377  
 Bleistein, C. A., 56, 58, 60, 379  
 Bock, R. D., 127, 136, 138, 377, 383  
 Bollen, K. A., 256, 258, 377  
 Bolt, D. M., 17, 133, 161, 377  
 Boughton, K. A., 17, 380  
 Box, G. E. P., 130, 261, 377  
 Braddy, P. W., 265, 301, 382  
 Braun, H., 380, 386  
 Breslow, N., 35, 384  
 Brosseau-Liard, P., 281, 384  
 Brown, T. A., 264, 377  
 Browne, M. W., 258, 262, 377, 381  
 Byrne, B. M., 251, 270, 377
- Cai, L., xx, 377  
 Camilli, G., 12, 17, 377, 385  
 Candell, G. L., 18, 27, 382  
 Carver, C. S., 289, 378  
 Chalmers, R. P., 92–93, 378  
 Chernyshenko, O. S., 201, 335, 385  
 Cheung, G. W., 265, 301–302, 378  
 Chou, C. P., 259, 378  
 Clauser, B. E., 12, 27, 378  
 Cole, N. S., 29, 378, 381  
 Cook, L. L., 222, 386
- Cudeck, R., 262, 377  
 Curran, P. J., 259, 281, 378–379
- de Ayala, R. J., 133, 378  
 De Boeck, P., 38, 382  
 DeMars, C., 69, 378  
 DiStefano, C., 281–282, 284, 304, 379  
 Dolan, C. V., 281, 379  
 Donoghue, J. R., 18, 31, 36–37, 50, 56, 379,  
 387  
 Dorans, N. J., 10, 12, 18, 52, 56, 58, 60, 62,  
 213, 379, 383  
 Douglas, J., 135, 379  
 Draper, N. R., 130, 261, 377  
 Drasgow, F., 18, 27, 201, 335, 377, 385
- Edgington, E. S., 91, 379  
 Eignor, D. R., 222, 378  
 Embretson, S. E., 121–122, 129, 379  
 Enders, C. K., 19, 368, 379  
 Engelhard, G., 379  
 Everson, H. T., 383
- Facon, B., 22–24, 27–29, 381  
 Finch, H., 201, 335, 379  
 Finch, J. F., 259  
 Finney, S. J., 281–282, 284, 304, 380  
 Fleer, P. F., 10, 162, 384  
 Flora, D. B., 281, 381  
 Foss, T., 259, 380, 383  
 French, B. F., 27, 380
- Gierl, M. J., 17, 68, 76, 88, 97, 380–381  
 Goldstein, H., 7, 380  
 Gomez-Benito, J., 14, 380  
 Gotzmann, A. J., 17, 380  
 Greenland, S., 35, 384  
 Grima, A., 50, 387
- Haenszel, W., 10, 30–31, 33, 38, 40, 43, 47,  
 164, 179, 350, 358, 378–380, 382–386

*Author Index*

389

- Hambleton, R. K., 12, 21, 27, 110, 129–130, 133, 141, 161, 181, 243, 376, 378, 380, 382, 384, 387
- Harrell, F. E., 380
- Harrison, D., 130, 380
- Hastings, C. N., 140, 213, 381
- Haviland, M. G., 292, 384
- Hayes, A., 289, 378
- Hidalgo, M. D., 14, 380
- Hochberg, Y., 15
- Holland, P. W., 10, 12, 18, 30–31, 34–36, 53, 56, 213, 376, 379–380, 383, 385–386
- Holm, S., 15–16, 49, 336, 380
- Hoyle, R. H., 378, 382
- Hu, L., 259, 262–263, 278, 380
- Hunter, J. E., 29, 381
- Jodoin, M. G., 68, 381
- Joreskog, K. G., 259, 380
- Junker, B., 141, 383
- Kano, Y., 259, 380
- Kaplan, D., 281, 383
- Kirk, R. E., 181, 262, 381
- Klein, A., 334, 381
- Kline, R. B., 264, 381
- Kulick, E., 10, 18, 52, 213, 379
- Lapsley, D. K., 14, 181, 261, 385
- Laurenceau, J. P., 289, 378
- Levine, M. V., 213, 381
- Lieberman, M., 136, 138, 377
- Linn, R. L., 213–214, 381
- Lissitz, R. W., 166, 381
- Little, R. J. A., 368, 381
- Lord, F. M., 10, 14, 29, 108, 120, 138, 146, 161, 165, 169, 171, 177–183, 185, 188, 190, 192–193, 195, 199, 213, 216, 222–224, 227, 231, 237, 301, 377, 381, 385, 387
- MacCallum, R. C., 262, 381
- Magis, D., 22–24, 27–29, 38, 381
- Maller, S. J., 27, 380
- Mantel, N., 10, 30–31, 38, 40, 43, 47, 49–52, 164, 179, 350, 358, 378–380, 382–386
- Marco, G. L., 146, 180, 382
- Masters, G. N., 125, 382
- Mazor, K., 12, 27, 378
- McKinley, R. L., 128, 382
- Meade, A. W., 265, 301, 382
- Mellenbergh, G. J., 8, 382
- Micceri, T., 334, 382
- Miller, T., 82, 382
- Millsap, R. E., 1, 3, 18, 36–37, 68, 302, 359, 382, 386
- Molenaar, I. W., 112, 385
- Moore, T. M., 292, 384
- Moosbrugger, H., 334, 381
- Muniz, J., 21, 382
- Muraki, E., 120, 125, 383
- Muthen, B. O., 259, 383, 387
- Muthén, L. K., 383
- Nagelkerke, N. J. D., 68, 71, 74, 80, 383
- Nandakumar, R., 106, 383
- Narayanan, P., 31, 37, 69, 383
- Nering, M. L., 120, 386
- Nicewander, W. A., 152, 383
- Olivera-Aguilar, M., 302, 382
- Olsson, U. H., 259, 380, 383
- Orlando, M., 135, 143, 154, 383, 386
- Osterlind, S. J., 380
- Ostini, R., 120, 383
- Patz, R., 141, 383
- Phillips, A., 35, 383
- Raju, N. S., 10, 162, 165, 213–217, 219, 221–222, 224–225, 378, 381, 383
- Ramsay, J. O., 112, 384
- Rasch, G., 119, 125, 127, 129, 148, 156, 164, 178–179, 183, 214–216, 220, 243, 376, 379, 381–382, 384, 386
- Reckase, M. D., 128–129, 384
- Reise, S. P., 121–122, 129, 289, 292, 294, 379, 384
- Rensvold, R. B., 265, 301–302, 378
- Rhemtulla, M., 281, 384
- Robin, F., 12, 21, 384, 387
- Robins, J., 34, 384
- Rogers, H. J., 10, 37, 65, 110, 161, 380, 384, 386
- Roussos, L., 90, 106, 383
- Rubin, D. B., 368, 381
- Samejima, F., 120, 122–123, 127, 158, 166, 171–172, 174, 178, 183, 190, 193–194, 200, 202–203, 207, 209, 211–212, 237, 239, 384
- Satorra, A., 259, 272, 280–281, 284, 287, 354, 378, 385
- Savalei, V., 281, 384
- Scheines, R., 384
- Schmitt, A. P., 56, 58, 60, 62, 379
- Serlin, R. C., 14, 181, 261, 385
- Shealy, R., 10, 18, 86, 89, 213, 385
- Shepard, L. A., 12, 17, 214, 385

- Sijtsma, K., 112, 385  
 Silverman, B. W., 112, 384  
 Sinharay, S., 135, 385  
 Sireci, S. G., 21, 384  
 Somes, G. W., 43, 49, 385  
 Spearman, C., 245, 385  
 Spray, J., 82, 382  
 Stark, S., 201, 335, 342, 385  
 Steiger, J. H., 261, 385  
 Steinberg, L., 10, 30, 123, 125, 127, 162, 164, 183, 385–386  
 Stern, H. S., 135, 385  
 Stocking, M. L., 146, 180, 385  
 Stout, W., 10, 18, 86, 89–92, 213, 381, 385  
 Sugawara, H. M., 262, 381  
 Swaminathan, H., 10, 31, 37, 65, 110, 161, 380, 383–384, 386  
  
 Thayer, D. T., 10, 12, 18, 30–31, 34, 62, 106, 379–380, 387  
 Thissen, D., 10, 30, 123, 125, 127, 135, 143, 154, 162, 164, 183, 198, 200, 202, 345, 383, 385–386  
 Thomas, M. L., 289, 386  
 Thurstone, L. L., 246, 386  
 Troye, S. V., 259, 383  
 Tuerlinckx, F., 38, 382  
  
 Ullman, J., 272, 386  
 Uttaro, T., 18, 36–37, 386  
  
 van der Linden, W. J., 10, 120, 162, 384, 386  
  
 Wainer, H., 10, 30, 149, 162, 213, 376–377, 379–380, 385–386  
 Wald, A., 72–73, 78, 84, 177, 179–180, 187, 192–193, 198, 336–337, 340, 342–344, 347, 350–351, 353–356, 358, 386  
 Wardrop, J. L., 213, 381  
 West, S. G., 259, 289, 378  
 Widaman, K. F., 384  
 Wilson, A., 82, 382  
 Wingersky, M. S., 106, 138, 387  
 Wollack, J. A., 127, 387  
 Woods, C. M., 201, 387  
  
 Xing, D., 21, 382  
  
 Yeh, Y. L., 201, 387  
 Yen, W. M., 132, 135, 387  
 Yu, C., 259, 387  
  
 Zenisky, A. L., 12, 387  
 Zhang, Z., 289, 378  
 Zumbo, B. D., 14, 68, 70, 380, 387  
 Zwick, R., 50, 62, 106, 387

## Subject Index

- b*- and *a*-plot method, 166
- bivariate outliers, 167
- disadvantages, 166, 177
- MeasInv**
  - `a.plot`, 171
  - `b.plot`, 169
- mixed-format test data, 174
- polytomous data, 171
- principal axis line, 167
- principal axis regression, 167
- purification, 168
- strengths, 166
  
- CFA-based methods, 295
- conditioning variable, 11
  - external criterion, 11–12
  - internal criterion, 12
  - purification, 12–13
- confirmatory factor analysis (CFA), 245
  - assessment of model fit, 259
    - goodness-of-fit indices, 260–261
      - CFI, 261, 263
      - RMSEA, 261
        - hypothesis test, 262
      - SRMR, 261
    - hypothesis testing, 260–261
      - fit statistic, 261
    - residual analysis, 260
      - raw and standardized residuals, 260
  - bifactor model, 288
    - general factors, 288
    - specific factors, 288–289
  - categorical indicators, 281
    - robust diagonally WLS, 283
    - threshold parameters, 282
  - common factor model, 246
  - defining the latent variable scale, 253
  - exploratory factor analysis, 245
    - factor, 245
    - factor analysis, 245
    - factor loading, 247
  - factor loadings
    - interpretation, 249
  - indicators, 245
  - interpretation of parameter estimates, 265
    - convergent and discriminant validity, 267
    - exploratory factor analysis, 269
    - factor loadings and intercepts, 266
    - modification indices, 269
    - residual variances, 267
  - model comparison, 264
    - change in goodness-of-fit indices, 265
      - chi-square difference test, 264
  - model identification, 251
    - just-identified, 251, 253
    - over-identified, 253
      - rules for determining model identification, 255
    - under-identified, 251, 253
  - model re-specification, 268
  - model specification, 250
  - Mplus
    - continuous indicators, 270
    - dichotomous indicators, 284
    - polytomous indicators, 287
  - parameter estimation, 256
    - maximum likelihood estimation (MLE), 257
    - model-implied covariance matrix, 256
    - Satorra-Bentler adjustment, 259
    - weighted least squares (WLS), 258
  - path diagram, 251
  - system of equations, 249
  - unique variance, 246  
- delta ( $\Delta$ ) metric, 19
- `deltaPlotR`, 23
- differential bundle functioning (DBF), 5
- differential distractor functioning (DDF), 57
- differential functioning of items and tests, 222
  - DFIT, 226
    - `Cdif`, 233
    - `Dtf`, 235

- differential functioning of items and tests (cont.)
  - Ipr, 231
  - IprNcdif, 232
  - Ncdif, 228
  - PlotNcdif, 232
- distance between IRFs, 223
- indices
  - compensatory DIF (CDIF), 226
  - differential test functioning (DTF), 225–226
  - non-compensatory DIF (NCDIF), 224
    - significance test based on chi-square test statistic, 224
    - significance based on item parameter replication, 225
- differential item functioning (DIF)
  - bidirectional, 9–10
  - definition, 5, 161
  - dimensionality, 295
  - item parameter drift, 7
  - nonuniform, 8
  - unidirectional, 9–10
  - uniform, 8
- differential test functioning (DTF), 5
- hypothesis testing, 13–14
  - blended approach, 14
  - challenge, 13
  - practical significance, 13
  - range-null hypothesis, 14
  - Type I error rates, 14
- IRT-based methods
  - attractive features, 161–164
  - weaknesses, 164–166
- item response theory (IRT), 108
  - assumptions, 129
    - dimensionality, 130
    - local independence, 131
    - shape of the IRF, 133
  - attractive features, 110
  - estimation software, 152
  - information functions, 146
    - conditional reliability, 152
    - conditional standard error of estimate, 151
    - item information, 146–147
    - test information, 149
  - invariance property, 110
  - item response function (IRF), 108
  - latent variable scale, 141
    - test characteristic curve, 141
    - test characteristic function (TCF), 146
  - linking scales, 143
    - invariance property, 143, 145
    - linear transformation, 145
    - transformation methods
      - mean-sigma, 146
      - Stocking and Lord test characteristic curve method, 146
- models, 111
  - generalized partial-credit model, 125
  - multidimensional two-parameter logistic model, 128
  - one-parameter logistic model, 118
  - Rasch model, 120
  - Samejima's graded responses model, 120
  - three-parameter logistic model, 112
  - two-parameter logistic model, 117
- parameter estimation, 136
  - joint maximum likelihood estimation (JMLE), 136
  - marginal maximum likelihood estimation (MMLE), 138
  - Markov chain Monte Carlo estimation, 136
- scale indeterminacy issue, 109
- likelihood-ratio test, 198
  - compact versus augmented model, 198
  - concurrent calibration, 200
  - IRTLRDIF computer program, 201
    - batch mode, 206
    - input file, 207
  - LR test statistic, 198
  - post-hoc analyses, 199
  - role of anchor items, 201
  - strengths and flexibility, 199
- logistic regression method
  - advantages, 65, 69
  - dealing with missing data
    - incorporating IRT proficiency estimates, 105
- MeasInv**
  - DIF.Logistic, 105
- dichotomous data with three or more groups
  - MeasInv**
    - DIF.Logistic.MG, 80
  - omnibus hypothesis, 76
- dichotomous data with two groups
  - effect size
    - log-odds ratio, 69
    - pseudo- $R^2$ 
      - Jodoin and Gierl criteria, 68
  - likelihood, 67
  - likelihood-ratio test, 67
  - logistic regression model, 66
  - matching variable, 66
- MeasInv**
  - DIF.Logistic, 70
- testing uniform and nonuniform DIF, 66
- using hierarchical approach, 68

- disadvantage, 69
  - polytomous data
    - logistic curves, 82
  - MeasInv**
    - DIF.Logistic, 86
  - purification, 69
  - rms**
    - lrm, 70
  - longitudinal measurement invariance, 359
    - configural invariance
      - baseline model with correlated residuals, 360
    - metric invariance, 363
    - scalar invariance, 365
  - Lord's chi-square DIF method, 178
    - effect size under 1PLM
      - delta odds ratio metric, 179
    - follow-up tests, 179
  - irtplay**
    - covirt, 183
  - MeasInv**
    - LordChi, 183
    - plot.ICC, 188
  - mixed-format test data, 195
  - omnibus null hypothesis for 3PLM, 178
  - polytomous data, 190
  - purification procedure, 180
  - test statistic for 1PLM, 178
  - test statistic for 3PLM, 178
  - testing range-null hypothesis, 181
    - advantages, 181
    - non-centrality parameter, 181
  - Wald statistic, 179
- Mantel–Haenszel method
- appealing features, 47
  - dealing with missing data
    - Zwick, Thayer, & Wingersky (ZTW) method, 105
  - dichotomous data with three or more groups
    - contingency table, 43
  - difR**
    - difGMH, 45
    - generalized MH statistic, 43
  - dichotomous data with two groups
    - contingency table, 31
  - difR**
    - difMH, 38
  - effect size
    - $\Delta$ -metric, 34
    - common odds ratio, 34
    - confidence interval for  $\Delta$ -parameter, 35
    - $P_{DIF}$ , 35
    - standard error for  $P_{DIF}$ , 36
    - standard error of log odds ratio, 35
- MeasInv**
- CI.for.D, 41
  - PDF, 41
  - odds ratio, 33
  - test statistic, 33
- limitations, 36
- matching variable, 31
- polytomous data
- contingency table, 49
  - generalized MH statistic, 49
  - Mantel statistic, 49
- MeasInv**
- GMH.poly, 51
  - Mantel.poly, 50
- MeasInv**
- plot.ICC, 171
- measurement invariance
- definition, 1–5
  - functional relationship, 2–5
- multigroup confirmatory factor analysis (MG-CFA), 296
- attractive features, 296
  - categorical indicators, 316
    - delta and theta parameterization, 317
  - continuous indicators
    - Mplus shortcut for testing invariance, 315
  - continuous versus categorical indicators, 303
  - effect sizes, 301
    - change in CFI, 302
    - proportion of the group difference in means on the indicator, 302
  - extension to multidimensional models, 331
  - more than two groups, 331
  - Mplus with continuous indicators, 303
  - partial measurement invariance, 300
  - reference indicator, 301
  - types of measurement invariance, 297
    - configural invariance, 297–298
    - metric invariance, 297–298
    - scalar invariance, 297, 299
    - strict factorial invariance, 297, 300
- multiple indicators, multiple causes (MIMIC)
- model, 332
  - continuous versus categorical indicators, 337
  - equation for testing uniform DIF, 333
  - interaction term for testing nonuniform DIF, 334
  - moderated structural equations method, 334
  - more than two groups, 358
  - Mplus with categorical indicators, 345
    - odds ratio effect size, 351
    - robust MLE, 351
  - Mplus with continuous indicators, 338

- multiple indicators, multiple causes (MIMIC)
- model (cont.)
  - testing DIF using the MIMIC model
    - baseline model, 335
    - likelihood-ratio test, 336
    - modification indices, 337
    - Wald statistic, 336
- observed-score methods, 17
  - advantages, 17
  - conditioning variable, 18
  - disadvantages, 17–18
  - missing data, 18
  - purification, 18
- R platform, 369
  - downloading and installing R, 369
  - functions, 373
  - inputting data, 371
  - packages, 373
  - R console, 370
  - reading data into R
    - foreign package, 373
    - read.fwf, 373
    - read.table, 373
  - script file, 370
  - updating R
    - installr**
    - updateR, 375
- Raju's area DIF measures, 213
  - area between the IRFs, 213
  - difR**
    - difRaju, 216
  - effect size under Rasch model, 216
  - purification, 213
  - signed area measure (SA), 214
    - 2PLM, 215
    - 3PLM, 215
    - Rasch model, 214
  - test statistic, 215
  - unsigned area measure (UA), 214
    - 2PLM, 215
    - 3PLM, 215
    - Rasch model, 214
- SIBTEST method
  - adjusted conditional item means, 89
  - CATSIB, 106
  - differential bundle functioning (DBF), 101
  - differential test functioning (DTF), 104
  - MeasInv**
    - SIBTEST.exp
      - dichotomous data, 97
      - polytomous data, 101
- mirt**
  - SIBTEST, 93
    - dichotomous data, 93
    - polytomous data, 99
  - strengths, 88
  - testing DIF classification criteria, 90
  - testing nonuniform DIF (CSIBTEST), 90
    - effect size, standard error for  $\hat{\beta}_{CRO}$ , 91
    - effect size,  $\hat{\beta}_{CRO}$ , 91
    - hypothesis test based on Chalmers, 92
    - hypothesis test based on randomization procedure, 91
  - testing uniform DIF, 88
    - effect size,  $\hat{\beta}_{UNI}$ , 89
    - effect size, standard error for  $\hat{\beta}_{UNI}$ , 90
- standardization DIF method
  - dichotomous data with two groups
    - conditional *p*-values, 53
    - differential distractor functioning (DDF), 57
  - difR**
    - difStd, 57
  - effect size
    - DIF classification benchmarks
      - DBS, 58
      - ETS  $\Delta$ -scale, 58
    - standard error of  $STD_{P-DIF}$ , 55
    - $STD_{P-DIF}$ , 55
  - MeasInv**
    - plot.cond.p, 60
    - nonparametric regression, 54
    - purification procedure, 58
  - matching variable, 53
  - polytomous data
    - effect size
      - benchmarks for *SMD*, 106
      - standardized mean difference (*SMD*), 62
  - MeasInv**
    - plot.cond.exp, 65
    - SMD*, 63
- test validity, 5
  - construct irrelevant factor, 7
  - internal structure, 6
- transformed item difficulty (TID) method, 19
  - advantages, 29
  - criterion to flag items, 21
  - delta ( $\Delta$ ) metric, 19
  - delta-plot, 19–20
  - deltaPlotR**
    - deltaPlot, 23
    - diagPlot, 24
  - polytomous data, 30
  - principal axis line, 20
  - principal axis regression, 21
  - purifying, 27
  - threshold value, 22