BOOK REVIEW

COMPUTATIONAL ASPECTS OF PSYCHOMETRIC METHODS BY MARTINKOVÁ & HLADKÁ

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As reported by Martinková, P., & Hladká, A. (Computational Aspects of Psychometric Methods: With R. Boca Raton, CRC Press, FL, 2023) *Computational Aspects of Psychometric Methods: With R.* Boca Raton, FL: CRC Press.

1. The Importance of the Book

Psychometric theory and methods are the foundation of psychological, educational, and behavioral measurement (Von Davier et al., 2021). However, the computational aspects of psychometric methods may be difficult for beginners to grasp because they require a detailed understanding of the statistical formulation of psychometric models and the computational methods for parameter estimation. While there are several proprietary software packages for estimating psychometric models, such as IRTPRO (Cai et al., 2011) and Winsteps (Linacre, 2022), the open-source statistical software R provides a comprehensive solution for psychometric data analysis (Choi & Asilkalkan, 2019). There are several excellent books on introducing psychometric models using R (e.g., Desjardins & Bulut, 2018; Mair, 2018). Yet, Martinková and Hladká (2023) book differs from previous ones mainly in two features. First, it focuses on both statistical formulation and computational aspects of psychometric methods and the comparison of different R packages to implement these models. Second, it presents tutorials based on the ShinyItem-Analysis application (a shiny-based interactive platform), which can enhance the assessability of psychometric methods to a broader range of readers.

2. Prerequisite Knowledge and Targeted Readers

In terms of prerequisite background knowledge for understanding psychometric models and methods for parameter estimation, prior knowledge in calculus, probability, and computational statistics (Givens & Hoeting, 2012) is preferred, as the book elaborates on the mathematical formula of psychometric models and demonstrates how to conduct the parameter estimation using maximum likelihood estimation and Markov chain Monte Carlo. In terms of the background knowledge required to put the theory into practice, little prior knowledge is needed, as the book

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shows how to install the Rstudio and R packages from scratch and uses the ShinyItemAnalysis application to show how to implement different psychometric models.

As such, this book will be valuable to different groups of readers. On the one hand, readers who are new to this area may benefit from the introduction of the various psychometric models, accompanied by detailed and straightforward interpretations of the output produced by both R packages and the ShinyItemAnalysis application. On the other hand, readers with sufficient statistical background may benefit from the comparison of different statistical software and different approaches to parameter estimation. Therefore, the book can serve as an introductory tutorial suitable for those readers who are new to the area of psychometrics (e.g., undergraduate students) and it is also intended for those researchers who are interested in learning the computational aspects of psychometric methods.

3. Structure and Summary of the Book

The book comprises 10 chapters covering different psychometric models and parameter estimation methods. Initial Chapters (1–4) focus on the introduction to psychometrics and methods to evaluate validity and reliability in psychometrics. The following two Chapters (5–6) delineate item analysis based on classical test theory and generalized linear models. The middle part of the book (Chapters 7–8) deals with a series of item response theory (IRT) models. The remaining chapters of the book (Chapters 9–10) cover the application and outlook of IRT models in psychometrics. The book also provides an introduction to R, supplementary material on random variables, and most importantly the exercises for each chapter at the end of the book. Each chapter begins with an introduction and then goes into the computational aspects of psychometric methods and R syntaxes to implement psychometric models, which ends with a summary. The main content of each chapter can be summarized as follows.

Chapter 1 provides an introduction to psychometrics, covering the history and potential applications of psychometrics, as well as the data and R packages used in the book. Readers can find all the materials accompanied by the book on GitHub (https://github.com/patriciamar/ PsychometricsBook). Chapter 2 focuses on the methods that can be used to provide evidence of external validity, such as ANOVA and regression models. Chapter 3 focuses on the psychometric methods for internal validity, which include cluster analysis and factor analysis. Chapter 4 is devoted to reliability in psychometrics, covering the definition of reliability, ways to estimate reliability, and potential sources of error from a generalizability theory perspective. Chapter 5 delves into the topics of traditional item analysis, which covers item difficulty, item discrimination, item characteristic curve, distractor analysis, etc. Chapter 6 demonstrates item analysis based on generalized linear models which can be viewed as special cases of IRT models (De Boeck, 2004) . The regression models for continuous, binary, and polytomous items are presented and computational aspects of parameter estimation of the models are also introduced. The methods for model selection, such as including the Akaike information criterion (AIC) and Bayesian information criterion (BIC) are also included to evaluate which model is better for given data. Chapter 7 demonstrates how to estimate various IRT models for binary items using various packages. Chapter 8 deals with more complex IRT models, introducing the cumulative logit IRT models (e.g., graded response model), adjacent-categories logit IRT models (e.g., rating scale model), baseline-category logit IRT models (e.g., nominal response model), and multidimensional IRT models. It also shows how to estimate the parameters of IRT models from both frequentist and Bayesian perspectives. Chapter 9 introduces different types of methods for detecting differential item functioning. These methods include traditional methods (e.g., Mantel-Haenszel test), methods based on regression models (e.g., logistic regression), and methods based on IRT models. Chapter 10 focuses on the

outlook for potential application scenarios and other important topics in psychometrics, including computerized adaptive testing, test equating, and the role of big data in psychometrics.

4. Strengths and Weaknesses

The book boasts several remarkable strengths. First, it presents an easy-to-understand introduction to psychometrics, covering the basic concepts and essential formulas of psychometric models, which can help readers understand the details and connections of different psychometric models.

Second, although there are some similar books on this topic (e.g., Mair, 2018; Price, 2016), this book stands out for its reader-friendly tutorial based on the ShinyItemAnalysis application, which can facilitate learning psychometrics in a straightforward and practical way. With the aid of the Shiny-based platform, even beginners with no R programming experience can perform psychometric data analysis. This can lower the learning threshold for those interested in learning psychometric methods. In addition, the book includes various R packages, such as mirt (Chalmers, 2012), ltm (Rizopoulos, 2006), and brms (Bürkner, 2017) and different types of psychometric models, which are valuable learning resources for practitioners of psychometrics to use different methods to solve real-world problems.

The third strong point of the book is that it elaborates on different computational methods for parameter estimation, such as joint maximum likelihood estimation, conditional maximum likelihood estimation, and marginal maximum likelihood estimation. It compares and evaluates these three likelihood-based methods, which can deepen our understanding of the differences and similarities between these different algorithms. It also delves into the computational methods when the closed form is not available. This is helpful for beginners to have a better understanding of the scenarios in which different algorithms are applicable.

The fourth merit of the book is that its useful learning materials are easily accessible on GitHub (https://github.com/patriciamar/PsychometricsBook), which contains all the R codes and datasets for readers to replicate the psychometric analysis demonstrated in the book. The book also clearly indicates this repository in the preface section, making it easy for readers to find related learning resources.

The fifth strength of the book is that it provides a series of exercises for each chapter at the end of the book. These exercises are based on the dataset provided on the book's website. This is especially useful for readers. On the one hand, readers can use these exercises to check their understanding of psychometric methods. On the other hand, they can embark on the path of learning by doing, which further enhances their practical skills.

However, there are a few things that could be improved in the next edition of the book. The first improvement concerns the R code in the book. Perhaps due to space limitations, most of the essential R code is shown in the book, but some is left out. Therefore, readers are encouraged to use the R files that accompany the book on Github, as they are more comprehensive and easier to use. After running all the R codes we found several minor typos in the R codes shown in the book. These typos were also included in the book webpage (https://www.cs.cas.cz/comps/CAPMbook/). It is not surprising that a few small typos slip into the R code, especially given the sheer volume of R code that accompanies the book. However, it would be beneficial to beginners if these typos could be corrected in the next edition.

Also, perhaps due to space limitations, the book covers several of the aforementioned likelihood-based methods for parameter estimation, but the book does not go into detail on the Bayesian approach to parameter estimation. Readers without sufficient statistical knowledge of Bayesian modeling might only scratch the surface of Bayesian IRT. One possible solution is to

list some suggested reading (e.g., Bürkner, 2021; Fox, 2010) at the end of each chapter so that readers can delve deeper into topics of interest.

Finally, as the title of the book suggests, the book focuses on psychometric methods. However, the book does not cover all types of psychometric models that one might encounter in practice. For example, cognitive diagnostic modeling, one of the most popular areas of psychometrics during the past decades (Desjardins & Bulut, 2018; Von Davier & Lee, 2019) , is missing. One plausible reason for this is space limitations and another might be that the purpose of the book is to introduce the psychometric methods covered in the ShinyItemAnalysis application. A possible solution might be that the book could introduce cognitive diagnostic models as an advanced topic in the last chapter, if possible.

5. Conclusion

As a whole, the book provides an introduction to the computational aspects of psychometrics, including the statistical models, methods for parameter estimation, and implementation using R and the ShinyItemAnalysis application. The book is well organized and easy to follow, as the chapters of the book are logically linked by the introductory section at the beginning of each chapter. This allows readers to build their knowledge map of the relationship between different topics of psychometric methods. In addition, readers will benefit from the tutorial on the mathematical formulations of psychometric methods, the examples of implementing various psychometric models using R and the ShinyItemAnalysis application, and the guidance on how to interpret the results produced by the software. This book can serve as an excellent tutorial for those researchers who are interested in learning psychometric methods and analyzing measurement data. As such, it is recommended for researchers in the fields of psychological, educational, behavioral, and health-related measurement.

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