Multidimensional Measurement Models Syllabus

PSQF 7375, Fall 2023

Note: The online syllabus will always have the most current information.

Course Information

Instructor:	Jonathan Templin
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Course website:	https://jonathantemplin.github.io/MultidimensionalMeasurementModels2023/
Office:	S210B Lindquist Center
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Classroom:	S210A Lindquist Center
Course Meeting Time:	W 12:30-15:20
Course Office Hours:	F 09:00-11:00 or by appointment

Course Introduction

Multidimensional Measurement Models is an advanced PhD-level course with a specialized focus on applications of measurement models with more than one latent variable, primarily in the fields of education and the social sciences. This comprehensive course is designed to provide an in-depth exploration of multidimensional item response theory (MIRT), diagnostic classification models (DCMs), and mixture models as essential tools for understanding complex psychological and social phenomena.

As contemporary psychological measurement in the educational and social sciences continues to grow in complexity, the need for sophisticated measurement techniques has become increasingly apparent. Traditional unidimensional measurement models often fall short in capturing the multifaceted nature of human attributes and behaviors, hindering accurate assessments and classifications. In response to these challenges, multidimensional measurement models, including mixture models, have emerged as powerful tools, enabling researchers and practitioners to more effectively measure and understand intricate constructs.

This course is designed for PhD-level students with a strong background in psychometrics, statistical modeling, and quantitative research methods. Participants should be familiar with basic unidimensional item response theory and have experience working with statistical software such as R.

Course Objectives

This course will provide students with an understanding of multidimensional measurement models, their theoretical underpinnings, and their practical applications in educational and social science contexts. By the end of the course, participants will be able to:

1. **Understand Multidimensional Item Response Theory (MIRT):** Delve into the foundational principles of MIRT, examining how it extends traditional unidimensional models to account for the measurement of multiple latent dimensions. Understand the mathematical and statistical intricacies involved in fitting MIRT models to empirical data.
2. **Analyze Multidimensional Data:** Gain proficiency in applying advanced statistical techniques to analyze multidimensional data. Explore methods for estimating latent trait scores, examining item characteristics, and assessing model fit for complex measurement structures.
3. **Interpret Diagnostic Classification Models (DCMs):** Explore diagnostic classification models, a class of psychometric models that focus on classifying individuals into latent classes or profiles based on their response patterns. Understand how DCMs enhance diagnostic accuracy by accounting for multidimensionality and differential item functioning.
4. **Examine Mixture Models:** Study mixture models as a class of multidimensional measurement models that account for heterogeneity within populations. Learn how mixture models can uncover distinct latent subgroups characterized by unique response patterns, shedding light on hidden structures within the data.
5. **Apply Models in Education and Social Sciences:** Discover the practical applications of multidimensional measurement models, including mixture models, in various domains. Explore how these models can inform decision-making, educational planning, and social intervention strategies.
6. **Critically Evaluate Research Literature:** Develop the skills to critically analyze and evaluate existing research studies that utilize multidimensional measurement models, including mixture models. Understand the advantages and limitations of these models in addressing complex research questions.

Course Structure

The course is organized into modules that progressively build a solid foundation in MIRT, DCMs, and mixture models. The modules will cover theoretical concepts, mathematical formulations, computational techniques, and practical implementation. Participants will engage in hands-on exercises, data analysis projects, and discussions to reinforce their understanding and application of these advanced measurement models.

Each class meeting (170 minutes) will be divided into four sections:

1. A lecture (approximately 80 minutes; from 12:30-13:50 each class meeting)
2. A break (10 minutes; from 13:50-14:00 each class meeting)
3. A discussion of the reading(s) from each week (approximately 20 minutes; from 14:00-14:20 each class meeting)
4. Coding/programming exercises (approximately 60 minutes; from 14:20-15:20 each class meeting)

Class will begin promptly at 12:30 each Wednesday. Please arrive by that time to limit distractions to those listening to lecture.

Tentative Course Schedule

Please see the main website for the most up-to-date schedule, required readings, and assignment information.

Date	Topic
Section 1	**Preliminaries**
08/23/2023	Introduction; What is Dimensionality; Estimation Toolbox
08/30/2023	Psychometric Prerequisites (Generalized Models, IRT, Structural vs. Measurement Models, Basic MIRT Models)
09/06/2023	Model Fit
Section 2	**Hard Reality of Multidimensionality**
09/13/2023	Multidimensional Difficulties (Identifiability, empirical identification, quantifying dimensionality)
09/20/2023	Estimation Methods (Marginal Maximum Likelihood; E-M Algorithm)
09/27/2023	Estimation Methods (Limited Information; Bayesian Methods)
Section 3	**Multidimensionality is Bad**
10/04/2023	Exploratory Models; Consequences of Multidimensionality; Unwanted Dimensionality
10/11/2023	Multidimensionality by Design (rater effects, testlets)
10/18/2023	Exploratory mixture models/Categorical Latent Variables (What is Dimensionality?)
Section 4	**Multidimensionality is Good**
10/25/2023	Confirmatory Models; Latent Variable Interactions
11/01/2023	Diagnostic Classification Models/Bayesian Networks
11/08/2023	Models with Specific Purposes (Higher order, bifactor, method factors, extreme response models, scoring approaches)
11/15/2023	Explanatory (Crossed Random Effect) models/G-Theory
11/22/2023	No Class (Thanksgiving Break)
11/29/2023	Multilevel Measurement Models
Section 5	**Multidimensionality is Desired**
12/06/2023	Construct Definitions and the Challenge of Subscores
12/13/2023	Final Exam

Coursework

There will not be a hybrid option this semester; all students are expected to attend class in person. If you are not feeling well, please do not come to class. You can watch the course videos when they are posted on YouTube, which should occur within 24 hours of the end of class.

Course Readings

The course will use a sample of book chapters and papers, with at least one reading assigned each week. The readings will be available on ICON. **You are expected to read the assigned readings before class and participate in the class discussion of each reading.**

Course Website/Technology

ICON **will** be used for grades, formative assessments, submission of assignments, disseminating course readings, and course communications.

ICON **will not** be used for lecture materials. Instead, we will use freely available commercial software for communication and dissemination of course materials. Course lecture slides, lecture examples, video files, assignments, and information are available on the website, https://jonathantemplin.github.io/MultidimensionalMeasurementModels2023/.

All lectures will be archived on YouTube (my YouTube channel is https://jonathantemplin.com/YouTube).

Statistical Computing

The course will use the R statistical package with the R Studio development suite along with a set of R packages (both Bayesian and Non-Bayesian). As we will be investigating several estimation methods, we will use a variety of R packages, Just Another Gibbs Sampler https://mcmc-jags.sourceforge.io/, https://mc-stan.org, and https://www.statmodel.com. All packages have been built into an Apptainer container that can be used on Argon, the University of Iowa's HPC cluster.

We will use Argon in our in-class coding exercises. To access Argon, you must have an SSH client installed on your machine. Mac and Linux users have SSH clients already installed, but Windows machines do not. If you are using a Windows machine, you will need to install an SSH client. I recommend https://www.chiark.greenend.org.uk/~sgtatham/putty/ for Windows users or installing the free Windows Subsystem for Linux (WSL) and using the SSH client in the WSL.

The University of Iowa enables access for many of these programs through their research computing resources: R Studio Notebooks: https://notebooks.hpc.uiowa.edu/ High Performance Computing: https://hpc.uiowa.edu/

Grading

Student evaluation will be made based three components: (1) homework assignments (50% of course grade), (2) formative assessments (20% of course grade), and (3) a one-on-one verbal final examination (30% of course grade).

Mathematically, the grade percentage can be expressed as:

$$GP = .5 \times HP + .2 \times FP + .3 \times F,$$

Where:

- GP is the Grade Percentage
- HP is the Homework Percentage
- FP is the Formative Assessment Percentage
- F is the Final Examination Percentage

Homework Assignments

There will be a set of homework assignments (the exact number to be determined). For each assignment, students will have a minimum of one week to complete the assignment. Homework assignments will weighted equally with respect to the 50% of the course grade accounted for by homework. The lowest homework percentage will be dropped (rather than allowing late homework).

Mathematically, the homework percentage can be expressed as:

$$HP = \left[\frac{\left(\sum_{h=1}^{H} P_h\right) - \min_h P_h}{H-1} \right],$$

where P_h is the percent correct on homework h, with H being the total number of homework assignments.

In order to be able to provide the entire class with prompt feedback, late homework assignments will not be accepted. However, extensions may be granted as needed for extenuating circumstances (e.g., conferences, family obligations) if requested at least three weeks in advance of the due date. Additionally, late homework due to emergencies will be accepted with documentation of the circumstances of the emergency.

All assignments must be completed in R, using R Markdown as a file format, and submitted via ICON. Although students are encouraged to work together on the concepts underlying homework, all answers must be from student's own work (writing and syntax) and not be copied or paraphrased from anyone else's answers. Grammar and writing will be assessed by each homework and will factor into the homework grade.

Formative Assessments

Each week, there will be a short formative assessment in ICON. The purpose of the formative assessment is to help students obtain a picture of their understanding of course materials. All genuine attempts (i.e., not haphazard answers) at completion will receive full credit. All formative assessments will be weighted equally with respect to the 20% of the course grade.

Verbal Final Examination

As we live in the era of large language models, rather than a written project, students will be required to complete a verbal final examination. The verbal final examination will be a one-on-one meeting with the instructor. The verbal final examination will account for 30% of the course grade.

The contents of the final will be the entirety of the course materials, with an emphasis on the readings and the homework assignments. The verbal final examination will be held from 12pm-4pm on Wednesday, December 13th. A sign-up sheet for an examination time blocks will be posted on ICON.

Course Grading System

Point Total	Letter Grade
100 and Above	A+
99-93	A
92-90	A-
89-87	B+
86-83	B
82-80	B-
79-77	C+
76-73	C
72-70	C-
69-60	D
Below 60	F

University of Iowa Course Policies and Resources for Students

Please see https://provost.uiowa.edu/student-course-policies for additional policies and resources.