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Bayesian inference for an item response model for modeling test anxiety

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ABSTRACT

We develop a Bayesian binary Item Response Model (IRM), which we denote as Test Anxiety Model (TAM), for estimating the proficiency scores when individuals might experience test anxiety. We consider order restricted item parameters conditionally to the examinees' reported emotional state at the testing session. We consider three test anxiety levels: calm, anxious and very anxious. Using simulated data we show that taking into account test anxiety levels in an IRM help us to obtain fair proficiency estimates as opposed to the ones obtained with three two-parameter logistic IRM (3PM) by Birnbaum (1957, 1968). For the 3PM, the proficiency estimates tend to be positively biased for both, calm and anxious examinees.

1. Introduction

There is an extensive concern about *test anxiety*. When we look for pages related to this issue on the Internet, we find about 4,980,000 sites. Many of then bringing counseling for dealing with the problem.

The Education Testing Services (ETS) recognizes that increased levels of test anxiety can hurt not only preparation to the test but also the general performance of those who suffer from it.

In 2005, the ETS made public at the Internet a document entitled "Reducing Test Anxiety—A Guide for Praxis Test Takers" (see www.ets.org/Media/Tests/PRAXIS/pdf/01361anxiety.pdf). This document describes some mental and physical symptoms of anxiety. Mental symptoms include mental black-out, difficulty concentrating, negative thoughts and knowing the answers after the test, but not while taking it. Physical symptoms include nausea, cramps, faintness, sweating and increased breathing rate. The document also points out to the test takers some practical tips about good study habits and strategies to cope with test anxiety.

Cizek and Burg (2005) provide helpful information on defining test anxiety and on what we can do about it. The book also provides specific actions that can be taken by teachers, parents, and students themselves to reduce test anxiety.

Some research about the relationship between test anxiety and performance has been carried out. Sarason (1984) analyzed the nature of test anxiety and its relationship to performance and cognitive interference from the standpoint of attention processes. Everson et al. (1994) studied the relationship between test anxiety and metacognitive word knowledge on performance on a standardized reading comprehension test. The study involved 117 college students to whom were given to complete three paper and pencil measures: (1) a self-report measure of test anxiety; (2) a metacognitive word knowledge task; and (3) a standardized measure of reading comprehension. Using multiple regression analyses the authors concluded that test anxiety caused a negative influence on students' performance on the metacognitive word knowledge task, independent of overall reading ability. They specifically concluded that when anxious worrying was low, increases in

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metacognitive word knowledge were associated with higher performance; and when anxious worrying was high, increases in metacognitive word knowledge were associated with lower levels of performance. Elliot et al. (1999) developed an extension of an integrative conceptualization of approach and avoidance achievement motivation by incorporating in the construct some elements of test anxiety. Using exploratory factor analysis, Proost et al. (2008) developed a two-dimensional measure of applicants' test anxiety, namely the Self-versus Other-Referenced Anxiety Questionnaire (SOAQ), that embeds worrisome cognitions of anxious applicants in the social evaluative context of "self" (Self-Referenced Anxiety) and "significant others" (Other-Referenced Anxiety). The authors remarked that "test anxiety has received limited attention in personnel selection research, although it may impair the test performance of applicants".

In this article we focus on a Bayesian extension of the three-parameter logistic Item Response Model (3PM) by Birnbaum (1957, 1968). We propose a methodology that allows for differential test anxiety levels in the estimation of the examinees' proficiency scores. Our model acknowledges the test taker's emotional stress and its consequential temporary cognitive interferences.

Using simulated data we show that taking into account test anxiety levels in an item response model help us to obtain fair proficiency estimates as opposed to the ones obtained with the 3PM model. For the 3PM, the proficiency estimates tend to be positively biased for both, calm and anxious examinees and negatively biased for the very anxious ones. An application to real data is also provided.

The article is organized as follows. In Section 2 we introduce some notation, the test anxiety model (TAM) as well as the likelihood. In Section 3 we present the Bayesian formulation. In Section 4 we present some simulated data description, MCMC convergence diagnostics and results. In Section 5 we present an application to real data and in Section 6 our concluding remarks.

2. An item response model accounting for test anxiety

2.1. Notation

We now introduce some notation. Let,

- $I =$ number of items in the analysis;
- $n =$ number of individuals or examinees taking a given exam.

Consider that the items are all binary and

$$u_{ij} = \begin{cases} 1 & \text{if examinee } j \text{ answers item } i \text{ correctly;} \\ 0 & \text{otherwise.} \end{cases}$$

- $G =$ number of test anxiety levels considered in the analysis.

Suppose that to each of the examinees who have taken the test is given a test anxiety score. Such score ranges from 1 to G, with 1 representing *no test anxiety* and G, *extreme test anxiety*.

Let,

$$v_{jg} = \begin{cases} 1 & \text{if examinee } j \text{ is given test anxiety level } g; \\ 0 & \text{otherwise} \end{cases}$$

and

- $v_j = (v_{j1}, \ldots, v_{jG})$, with $\sum_{g=1}^{G} v_{jg} = 1$;
- $g(j)$ indicates that examinee j belongs to group g;
- n_g is the number of examinees in test anxiety group g;
- $J(g)$ is the set of indexes j of examinees in anxiety group g;
- $\theta = (\theta_1, \ldots, \theta_n)$ is the proficiencies' vector;
- $\beta_2 = (\beta_{21}, \ldots, \beta_{2I})$ is the discrimination parameter vector;
- $\beta_{1i} = (\beta_{11,i}, \ldots, \beta_{1G,i})$ is the location parameter vector for item i;
- $\beta_1 = (\beta_{11}, \ldots, \beta_{1I})$ is the location parameter vector;
- c_i is the guessing parameter for item i;
- $c = (c_1, \ldots, c_I)$ is the guessing parameter vector;
- $\beta_i = (\beta_{1i}, \beta_{2i}, c_i)$ is the item parameters vector.