Let's talk about Thurstone & Co.: An information-theoretical model for comparative judgments, and its statistical translation

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Abstract

(to do)

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1. Introduction

In *comparative judgment* (CJ) studies, judges assess the presence of a trait or competence by conducting pairwise comparisons of stimuli (Thurstone, 1927; Pollitt, 2004, 2012a). The comparison produces a dichotomous outcome, indicating which stimulus is perceived to possess a higher level of the trait. After conducting multiple rounds of pairwise comparisons, researchers use the Bradley-Terry-Luce (BTL) model (Bradley and Terry, 1952; Luce, 1959) to process the outcomes and estimate scores that reflect the underlying trait of interest. CJ has been successfully employed in assessing the quality of written texts (Laming, 2004; Pollitt, 2012b; Whitehouse, 2012; van Daal et al., 2016; Lesterhuis, 2018; Coertjens et al., 2017; Goossens and De Maeyer, 2018; Bouwer et al., 2023).

Numerous studies have documented the effectiveness of CJ in assessing various traits and competencies over the past decade. These studies have emphasized three aspects of the method's effectiveness: its reliability, validity, and practical applicability. Research on reliability indicates that CJ requires a relatively small number of pairwise comparisons (Verhavert et al., 2019; Crompvoets et al., 2022) to produce trait scores that are as precise and consistent as those generated by other assessment methods (Coertjens et al., 2017; Goossens and De Maeyer, 2018; Bouwer et al., 2023). Furthermore, evidence suggests

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that the reliability and time efficiency of CJ are comparable, if not superior, to those of other assessment methods when employing adaptive comparison algorithms (Pollitt, 2012b; Verhavert et al., 2022; Mikhailiuk et al., 2021). On the other hand, research on validity suggests that scores generated by CJ can accurately represent the traits being measured (Whitehouse, 2012; van Daal et al., 2016; Lesterhuis, 2018; Bartholomew et al., 2018; Bouwer et al., 2023). Finally, research on practical applicability highlights the method's versatility across both educational and non-educational contexts (Jones, 2015; Bartholomew et al., 2018; Jones et al., 2019; Marshall et al., 2020; Bartholomew and Williams, 2020; Boonen et al., 2020).

Nevertheless, despite the growing number of studies on CJ, unsystematic and fragmented research approaches in the literature have left several critical issues unaddressed. This research primarily focuses on three: the apparent disconnect between CJ's measurement and structural model, the over-reliance on the assumptions of Thurstone's Case 5 (1927) in CJ's measurement model, and the unclear role of comparison algorithms on the method's reliability and validity. The following sections will discuss each of these issues in detail, followed by the introduction of a theoretical model and its statistical translation, which aim to address all three concerns simultaneously.

2. Three critical issues in CJ literature

2.1. The disconnect between structural and measurement models

In a typical CJ study, the BTL model serves as the measurement model for CJ (Andrich, 1978; Bramley, 2008). A measurement model specifies how manifest variables contribute to the estimation of latent variables (Everitt and Skrondal, 2010). For example, when evaluating text quality, the BTL model uses the dichotomous outcomes resulting from the pairwise comparisons (the manifest variables) to estimate scores that reflect the underlying quality level of the texts (the latent variable) (Laming, 2004; Pollitt, 2012b; Whitehouse, 2012; van Daal et al., 2016; Lesterhuis, 2018; Coertjens et al., 2017; Goossens and De Maeyer, 2018; Bouwer et al., 2023).

Researchers then typically use the estimated BTL scores, or their transformations, to conduct additional analyses or hypothesis testing. The literature indicates that these scores have been used to identify 'misfit' judges and stimuli (Pollitt, 2012b; van Daal et al., 2017; Goossens and De Maeyer, 2018), detect biases in judges' ratings (Pollitt and Elliott, 2003; Pollitt, 2012b), calculate correlations with other scoring methods (Goossens and De Maeyer, 2018; Bouwer et al., 2023), or test hypotheses related to the latent trait of interest (Bramley and Vitello, 2019; Boonen et al., 2020; Bouwer et al., 2023; van Daal et al., 2017; Jones et al., 2019; Gijsen et al., 2021).

However, the statistical literature cautions against using estimated scores to conduct additional analyses or tests. A key consideration is that BTL scores are parameter estimates that inherently carry uncertainty. Ignoring this uncertainty when conducting additional analyses and tests can inflate their precision and statistical power, increasing the risk of committing a type I error (McElreath, 2020), which is when a null hypothesis is incorrectly rejected (Everitt and Skrondal, 2010).

To mitigate these risks, principles from Structural Equation Modeling (SEM) (Hoyle, 2023; Kline, 2023) and Item Response Theory (IRT) (de Ayala, 2009; Fox, 2010; van der

Linden, 2017) recommend conducting these analyses and tests within a structural model that accounts for both the scores and their uncertainties, rather than treating them separately. Thus, an integrated approach combining CJ's structural and measurement models can offer significant advantages.

2.2. The assumptions of Case 5 and the measurement model

2.3. The role and impact of comparison algorithms

3. Theory

3.1. A theoretical model for CJ

3.2. From theory to statistics

4. Discussion

4.1. Findings

4.2. Limitations and further research

5. Conclusion

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6. Appendix

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