A Unified Latent Space Item Response Model for Test Security Diagnostics

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Multi-Modal Siloes

- The integrity of high-stakes assessments is threatened by security breaches like item preknowledge and leakage.
- Traditional detection methods are often siloed, analyzing item responses, response times and computer-interaction data in isolation.
- This siloed approach creates critical blind spots, as it fails to capture complex behavioral patterns that span across these multiple data streams

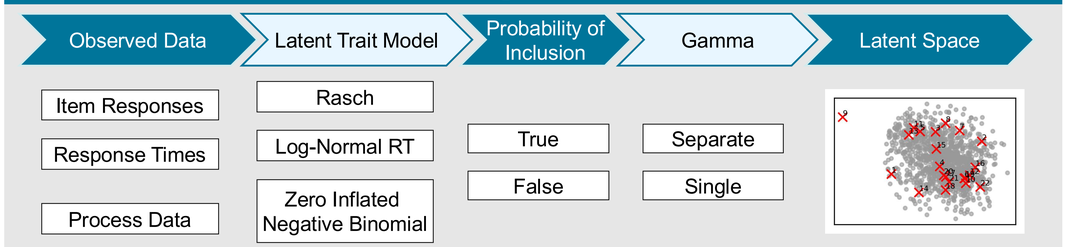
Unified Latent Space Framework

- We introduce a novel latent space item response model that unifies these multi-modal data streams into a single, cohesive framework.
- The model positions both persons and items in a shared geometric space, allowing for a holistic view of examinee behavior.
- This integrated approach is specifically designed to uncover subtle person-by-item interactions, which serve as powerful diagnostic indicators of item compromise.

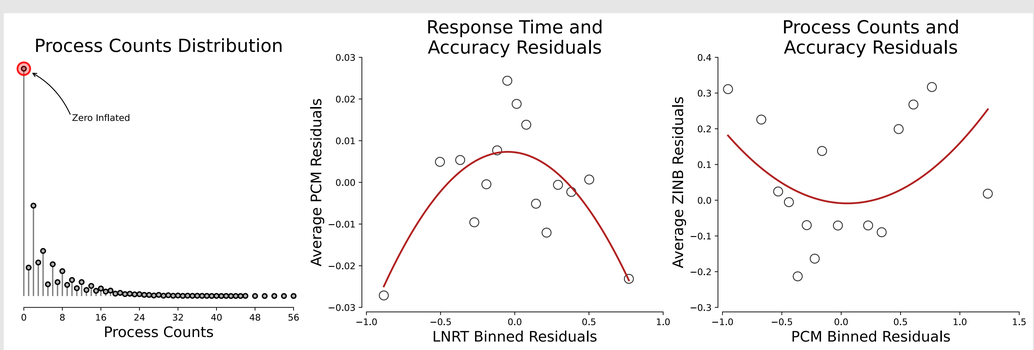
Unifying Modalities

- **Item Responses**: Modeled using the Rasch Partial Credit Model (PCM), person abilities are anchored on known scale.
- **Response Times**: Modeled with a Log-Normal Response Time (LNRT) model, capturing the characteristic speed of persons and time intensity of items.
- **Process Data**: Interaction counts (e.g., answer changes) are modeled via a Zero-Inflated Negative Binomial (ZINB) model to handle sparse and overdispersed data.

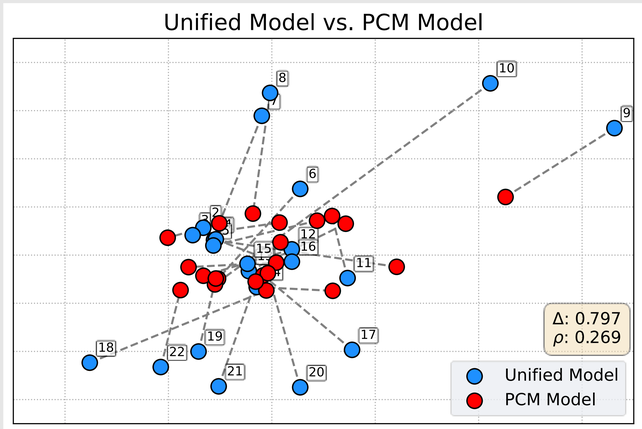
Modeling Framework

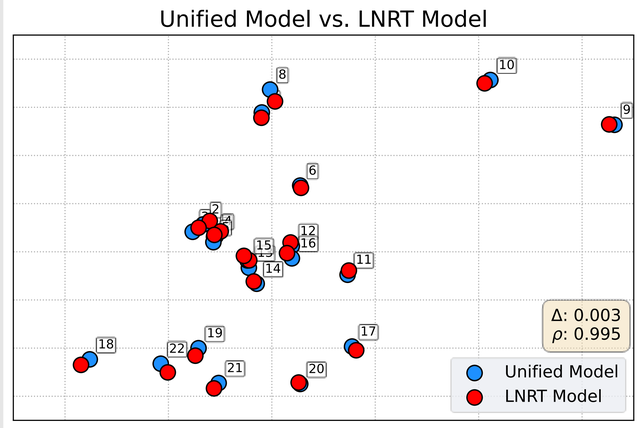


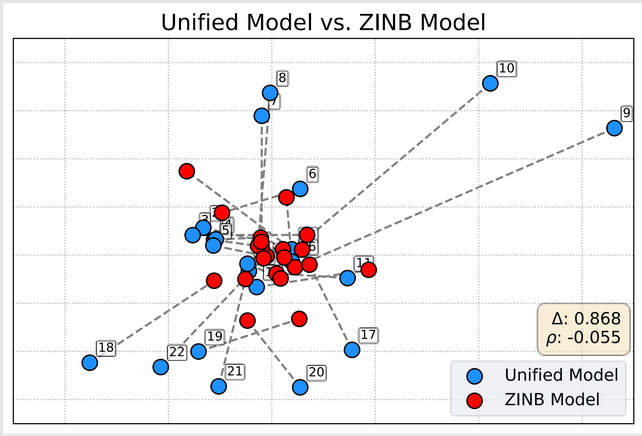
Descriptive Motivation



Unified-LS Separate Gamma

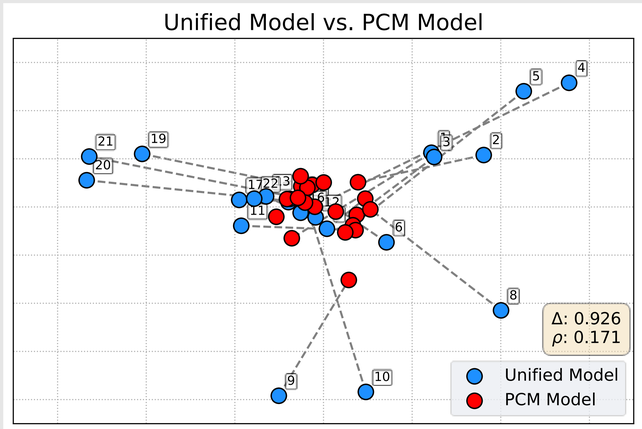


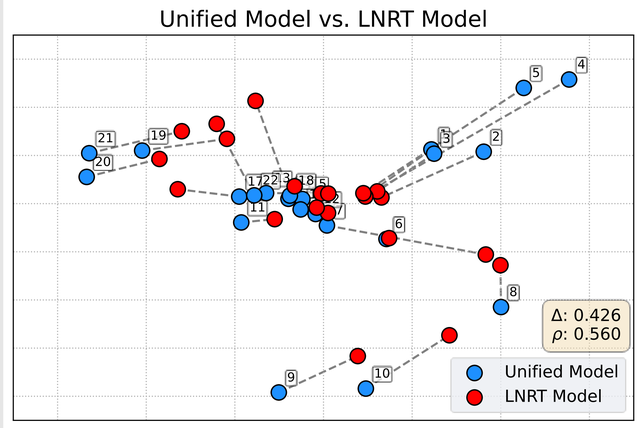


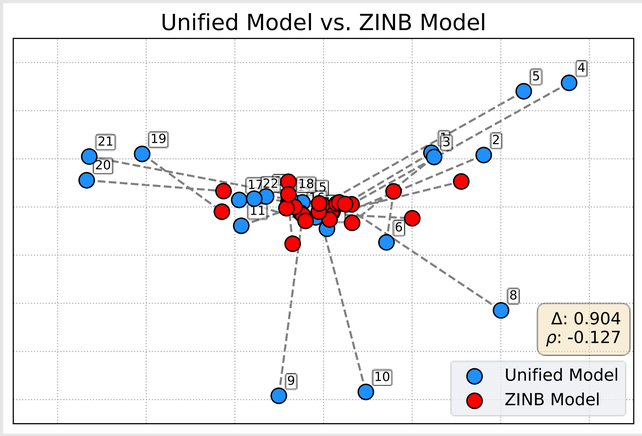


- 3-gamma LS is highly congruent with the RT-only space, indicates they provide the most salient signal of local item dependencies.

Unified-LS Single Gamma







- Single gamma attenuates the structural alignment with the RT-only space; single parameter forced to average the strong RT dependency with the weaker signals.

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