Ordinal Models

PSY 504

February 20, 2023

Princeton University

What is an ordinal variable?

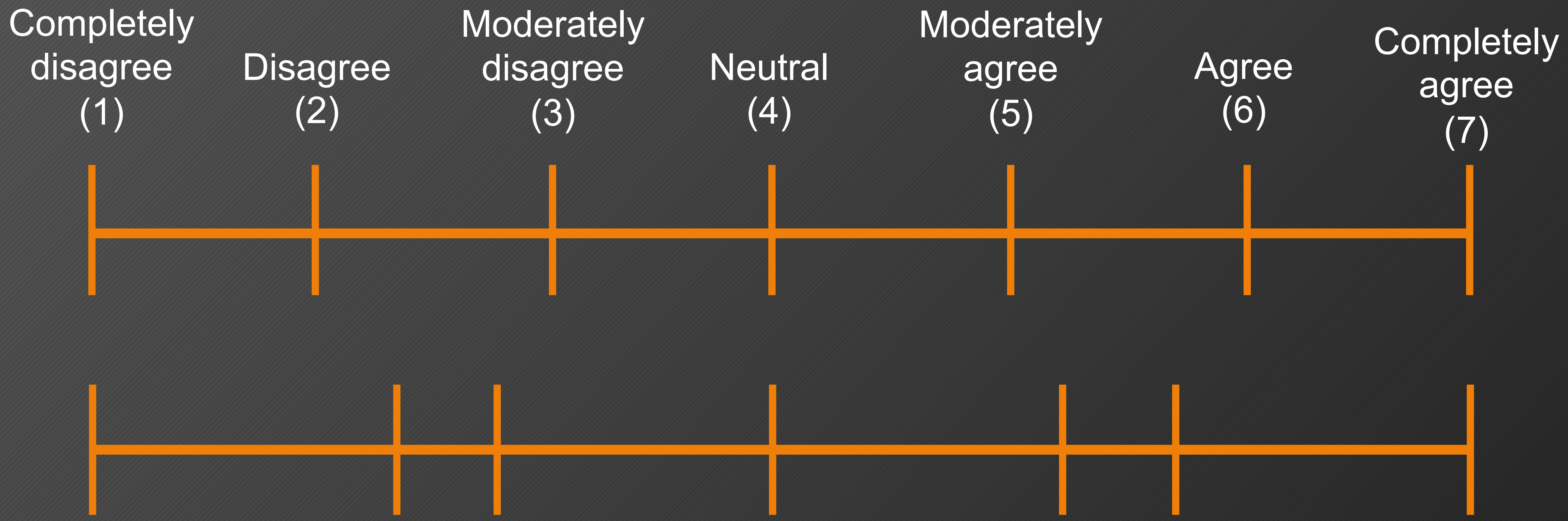
- A variable that consists of ordered, but discrete categories; there is a natural ordering to the categories
  - Examples:
    - Likert-scales
      - Strongly disagree, disagree, neutral, agree, strongly agree
      - Never, sometimes, often, always
    - Education level
      - High school degree, bachelor’s degree, master’s degree, etc.
- By contrast, metric variables are continuous and inherently quantitative (e.g., score on a math test).

Problems with treating ordinal data as metric

- Using models that assume data is metric (t-tests, ANOVA) for ordinal data, runs the risk of:
  - Low rates of correct detection
  - Distorted effect size estimates
  - Increased Type I error
  - Inversions of differences between groups

Why these problems?

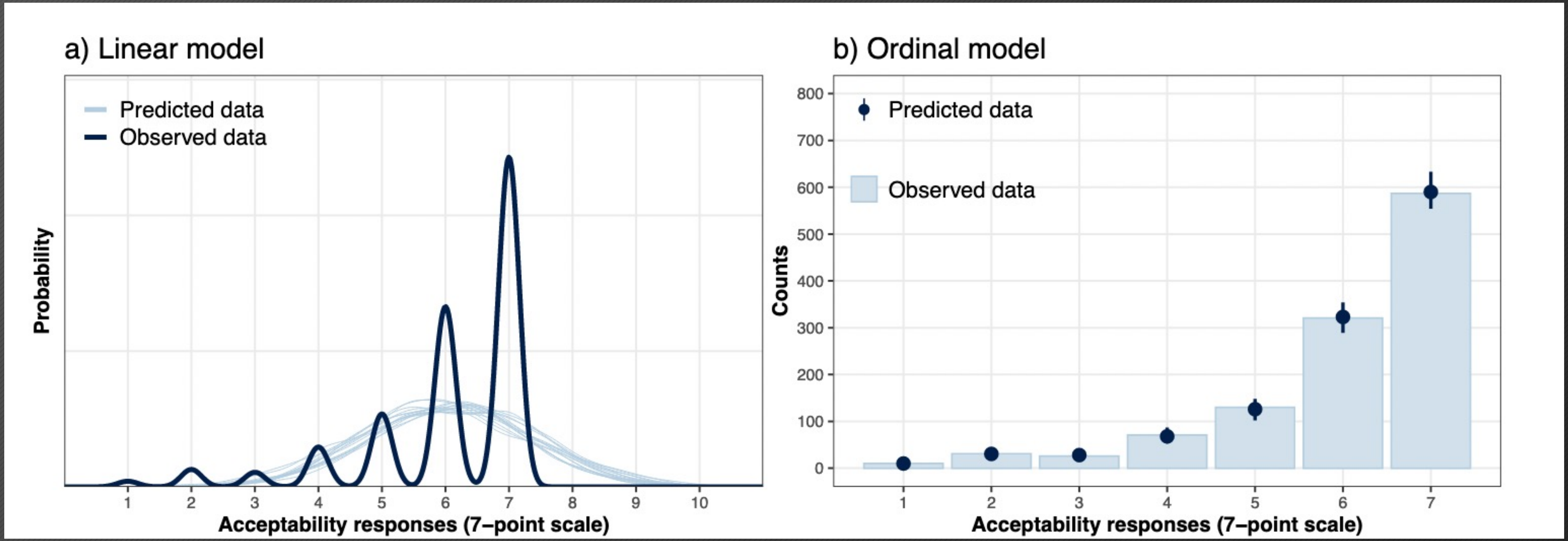
- Assumption of equidistance



Why these problems?

- Assumption of equidistance
- Distribution of ordinal variables may be non-normal
- Unequal variances of unobserved variables

Treating ordinal data as continuous vs. ordinal



Veríssimo (2021)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MODELS

What do ordinal models do?

- Predict discrete response categories
- Can handle non-normality
- Allow for unequal distances between responses

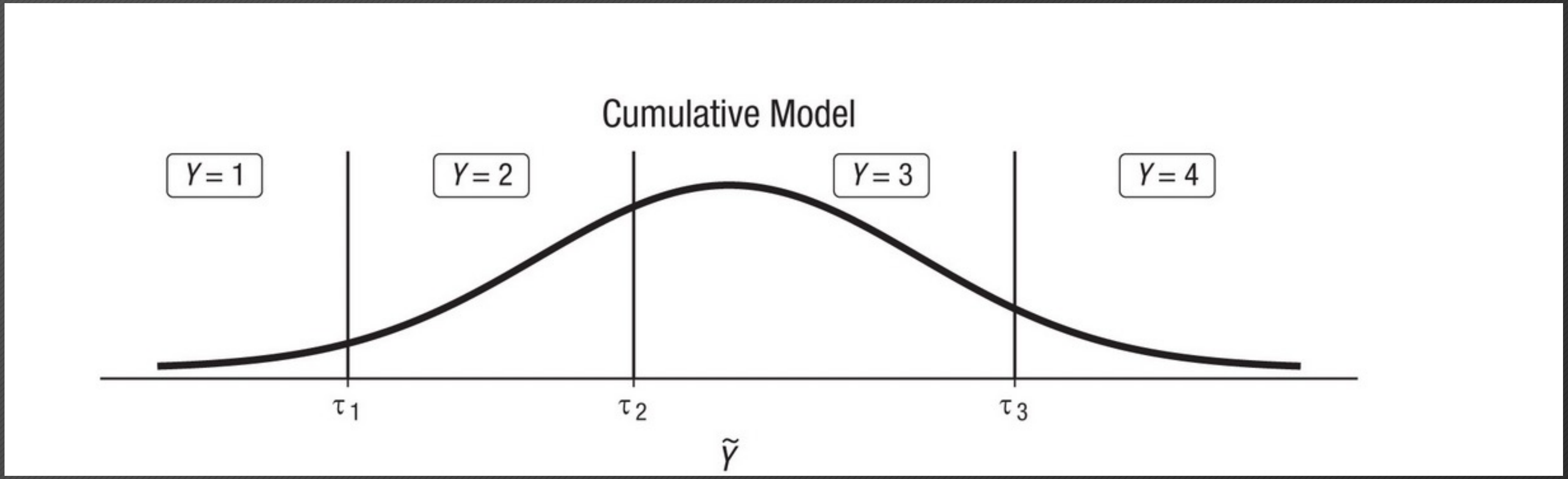
Three classes of ordinal models

- Cumulative models
- Sequential models
- Adjacent-category models

Cumulative model

- Good for Likert DVs, rating scales, etc.
- Assumes that observed ordinal variable *Y* originates from categorization of a latent (not observable) continuous variable $\tilde{Y}$
- Assumes $\tilde{Y}$ (the latent continuous variable) is normally distributed, with mean = 0 and SD = 1
- Assumes *K* thresholds ($\boldsymbol{\tau}_k$), which partition $\tilde{Y}$ into *K* + 1 observable and ordered categories of *Y*

Cumulative model



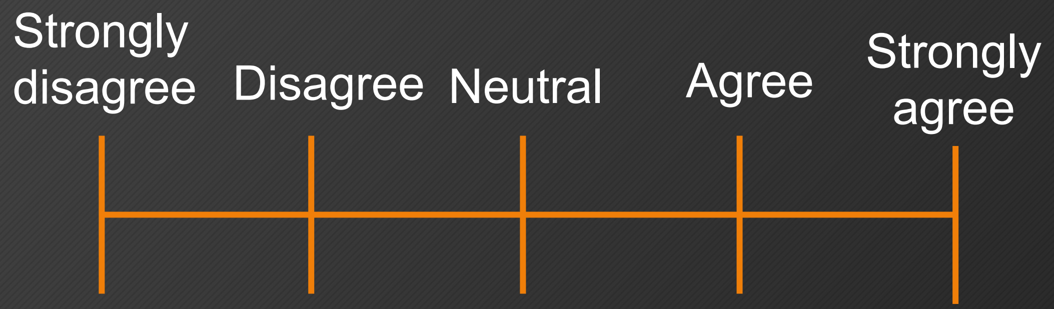
- Area under the curve in each bin represents the probability of the observed ordinal response Y

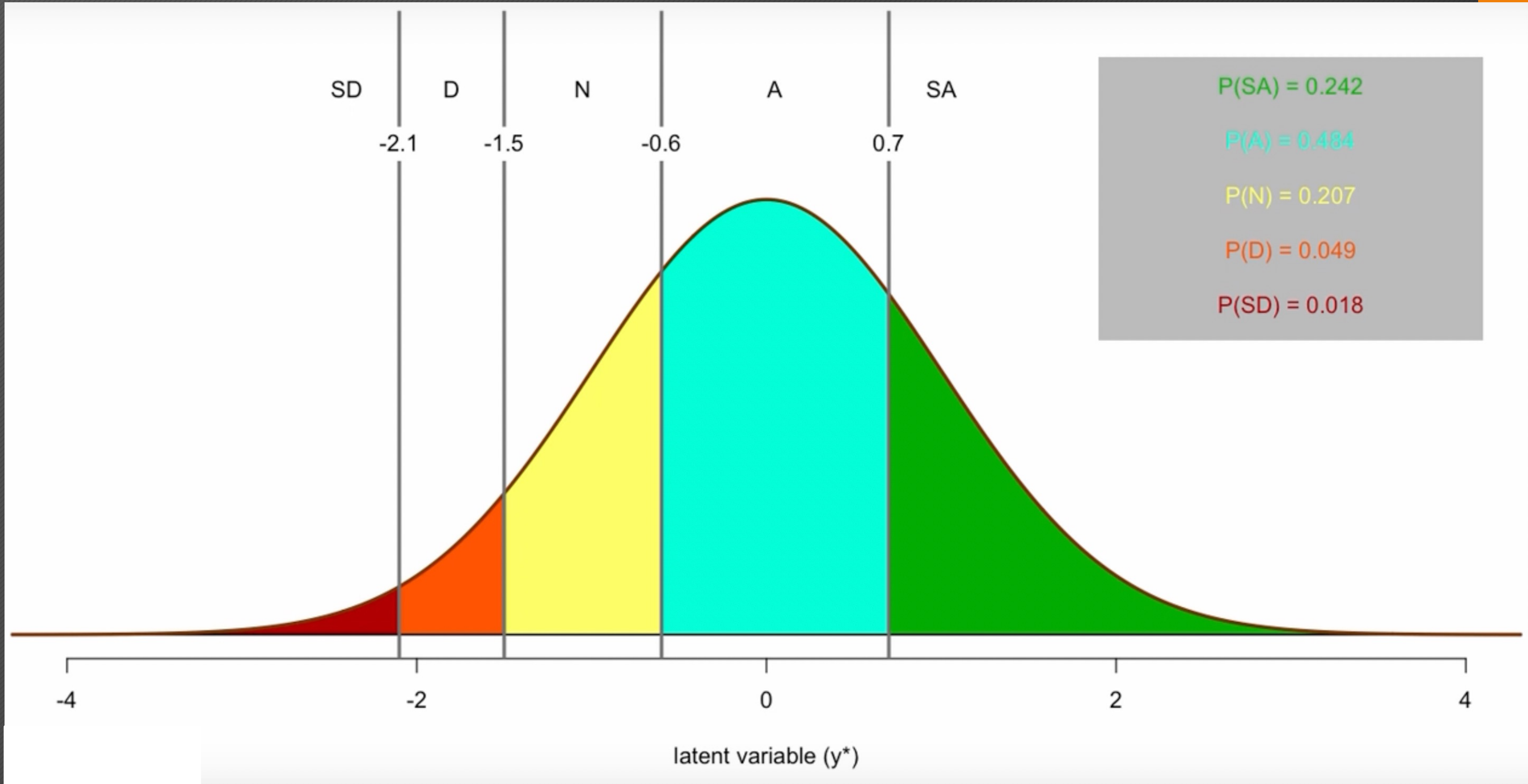
Bürkner & Vuorre (2019)

Example

Please rate your agreement with the statement below.

Graphic design is clearly the passion of the person who created this image:





https://www.youtube.com/watch?v=jWIJ7P1G9P4

Sequential model

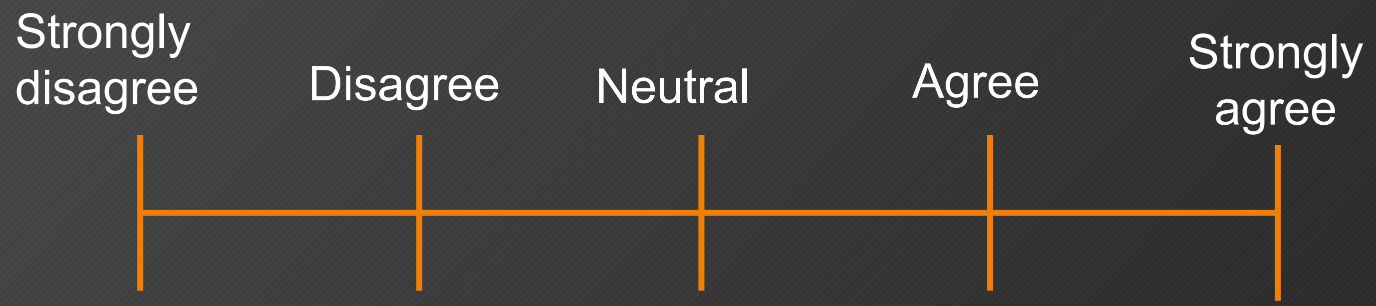
- Good for DVs resulting from a sequential process
- How do I know if it’s a sequential process?
  - “When a higher response category is possible only after all lower categories are achieved” (Burkner & Vuorre, 2019)
  - E.g., years of marriage before divorce

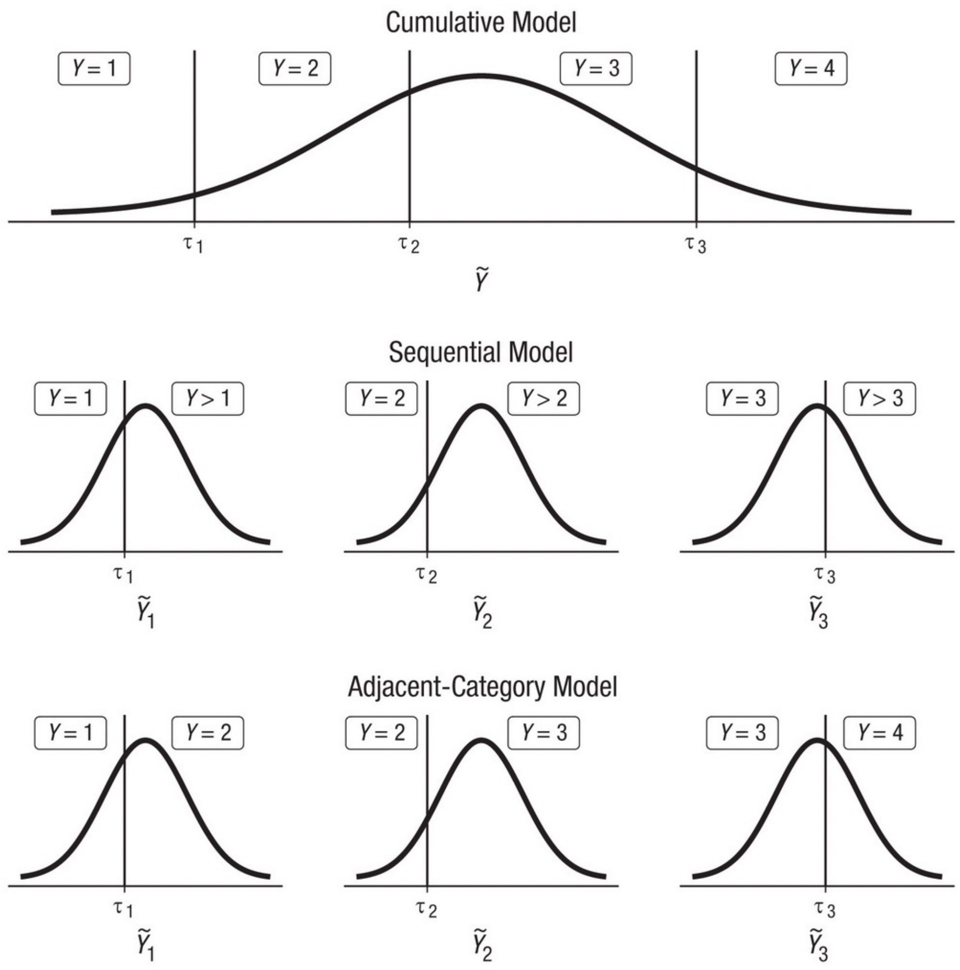
Sequential model

- Assumes that for every category *k,* there is a latent continuous variable $\tilde{Y}_k$ (standard normally distributed) that determines the transition between the *k*th and *k* + 1th category
- Thresholds ($\boldsymbol{\tau}_k$) separate categories.
- If $\tilde{Y}_k > \boldsymbol{\tau}_k$, the sequential process continues.
- The probability that *Y* falls in category *k* equals the probability that it did not fall in one of the former categories 1 to *k*-1, multiplied by the probability the sequential process stopped at *k*

Adjacent-category model

- Models the decision between two adjacent categories of $\tilde{Y}$
- Models the decision between $Y = k$ and $Y = k + 1$
  - Contrast this to sequential models, which model decision between $Y = k$ and $Y > k$
- Example: modeling the probability of choosing “agree” over “strongly agree”





Bürkner & Vuorre (2019)

Generalizing across the three classes

- Category-specific effects
  - A predictor could have different effects on the different response categories of Y
    - E.g., sympathy may affect people's ratings of "agree" vs. "neutral" in the graphic design example from Slide 12, but not people's ratings of "agree" vs. "strongly agree."
  - Sequential and adjacent-category models work best here.

- Unequal variances
  - When variance differs between groups, conditions, time, etc.
  - All three classes of models are good for this.

Lingering questions

- Are there any cases in which differentiating between cumulative and sequential models becomes especially difficult?

- How do you know if some of your effects might be category-specific?

References

- Bürkner, P. C., & Vuorre, M. (2019). Ordinal regression models in psychology: A tutorial. *Advances in Methods and Practices in Psychological Science*, *2*(1), 77-101.
- Veríssimo, J. (2021). Analysis of rating scales: A pervasive problem in bilingualism research and a solution with Bayesian ordinal models. *Bilingualism: Language and Cognition*, *24*(5), 842-848.
- https://www.youtube.com/watch?v=jWIJ7P1G9P4