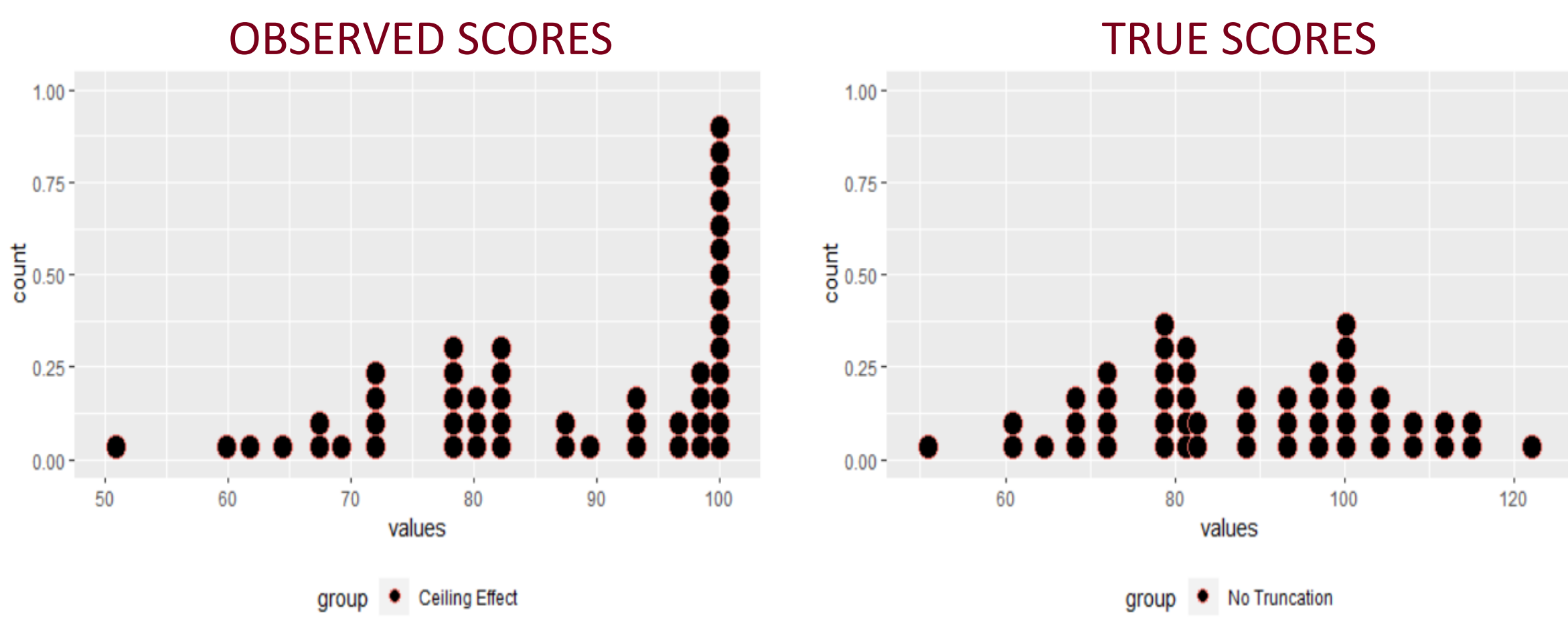


WHEN ANOVA ASSUMPTIONS FAIL

ANOVA models assume that data are normally distributed. While true scores may indeed be normally distributed, the presence of a ceiling or floor effect causes the observed scores to appear heavily skewed, as seen below.

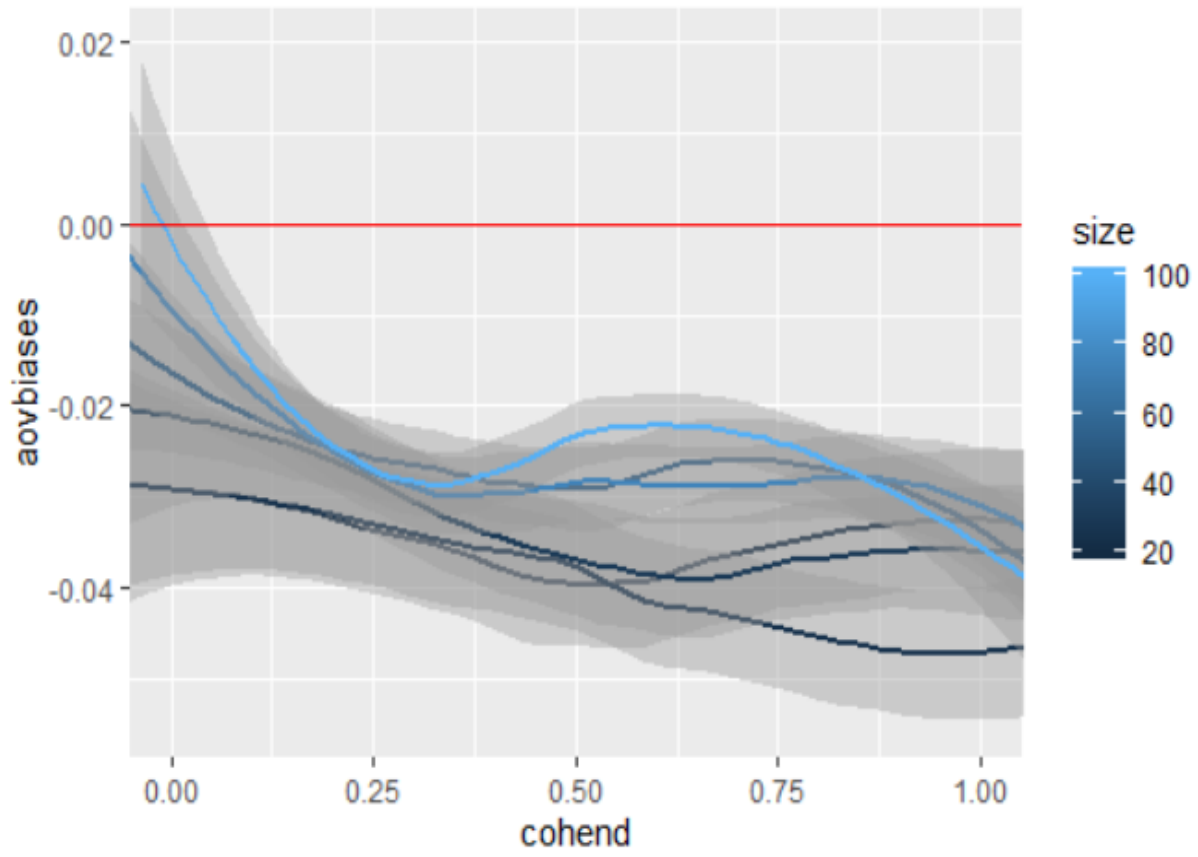


With a ceiling effect, observed scores at the ceiling are less than their true values, causing an underestimate of group means. With a floor effect, the opposite is true, with observed scores causing an overestimate of group means.

These errors inhibit the ANOVA model from accurately estimating differences between group means. This bias poses problems for researchers analyzing experimental data designed to compare the efficacy of different conditions. Determine whether an ANOVA model may still be appropriate for your data, regardless of your sample size, by checking your data against the “30-20” rule.

The 30-20 Rule

- (1) All groups must have less than 30% of their observations at the ceiling or floor, and
- (2) The difference in the proportion of observations at a ceiling or floor between groups should be no more than 20%.



When the 30-20 rule is met, ANOVA models will underestimate effect sizes by no more than 0.05. Thus, it may still be appropriate and useful to use ANOVA. However, when the 30-20 rule is violated, ANOVA models will severely underestimate effect sizes, and are no longer useful in estimating differences.

One alternative to ANOVA is a Tobit model. Tobit models explicitly aim to account for observed scores truncated at a floor or ceiling. It estimates differences in means through cumulative frequency distributions within the range of observed scores. Tobit models have a “70%” rule: All groups must have less than 70% of their observations at the ceiling or the floor. If so, Tobit models can estimate effect sizes for group mean differences with a bias less than 0.02.

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“Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful.”
(Box & Draper, 1987, p. 74)

When faced with **Ceiling and Floor Effects**, ANOVA models *underestimate* group differences.

One alternative is the **Tobit model**.

Decide which model to fit with **The 30-20 rule**.

Supplementary materials detail how to fit a Tobit model using R.

Choosing a statistical model amidst ceiling and floor effects

V.N. Vimal Rao¹, Kristin Running², and Robin Coddington³

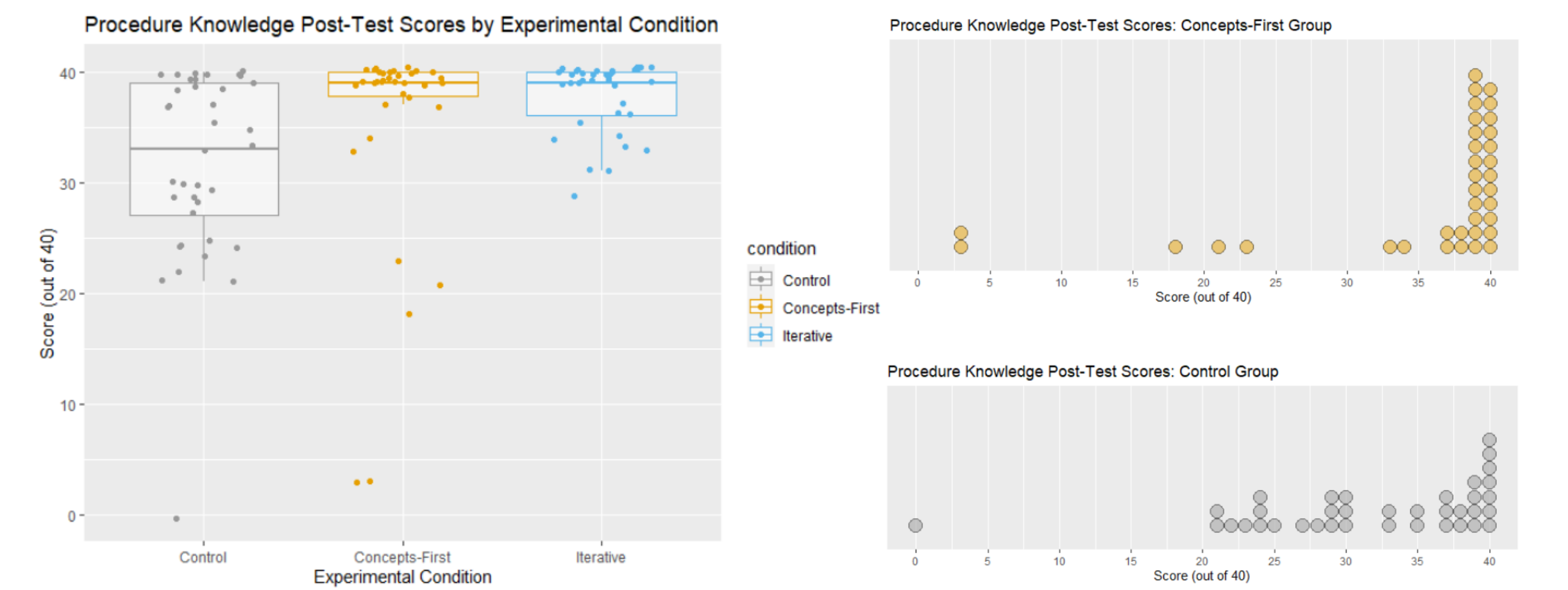
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²*School Psychology, College of Education and Human Development, University of Minnesota*

³*School Psychology, Bouvé College of Health Sciences, Northeastern University*

HOW TO FIT A TOBIT MODEL USING R

NOTICING AND ACKNOWLEDGING The first step for any analysis and statistical thinking is to first notice and acknowledge variability in the data. Create boxplots and dotplots to visualize the variability in a response variable.



FITTING A MODEL Our class-wide intervention utilized block randomization with pre- and post-testing, matching an ANCOVA model in design. However, our data violate the 30-20 rule, as 48.6% of observations in the Iterative condition are at the ceiling. Here, we instead use a Tobit model. We have done so in R.

```
ancova.model <- aov(  
  data = fraction_knowledge,  
  procedures_post ~ condition + procedures_pre  
)  
  
tobit.model <- vglm(  
  data = fraction_knowledge,  
  procedures_post ~ condition + procedures_pre,  
  family=tobit(Lower=0, Upper=40)  
)
```

Estimated Group Differences by Fitted Model		
Comparison Groups	ANCOVA	Tobit
Concepts-First minus Control	2.338	3.579
Iterative minus Control	4.174	6.579
Iterative minus Concepts-First	1.836	3.000

INTERPRETING RESULTS The R syntax for fitting an ANOVA model and Tobit model are very similar, as are the outputs from each model. Given Tobit models are easy to fit, and their benefits in accurately estimating group differences despite ceiling or floor effects, we highly recommend researchers consider using Tobit regression models when the 30-20 CFE rule is violated.

Our Methods

The “30-20 rule” and “70% rule” are supported by a simulation study examining the bias in ANOVA and Tobit models. Simulation parameters varied were the proportion of observations at the ceiling in each group and the between group effect size. See Running et al. (2021) for more information about the classwide intervention this data is from.

Supplementary Material

For a Tobit R Guide, R code, our dataset, a copy of this poster, our final proposal, and more, please visit
github.com/RaoVNV/NASP2021

