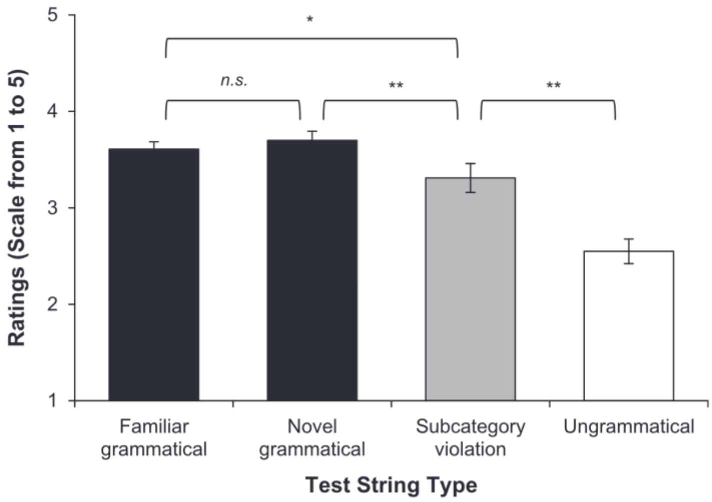
Three common mistakes in statistics and how to avoid them

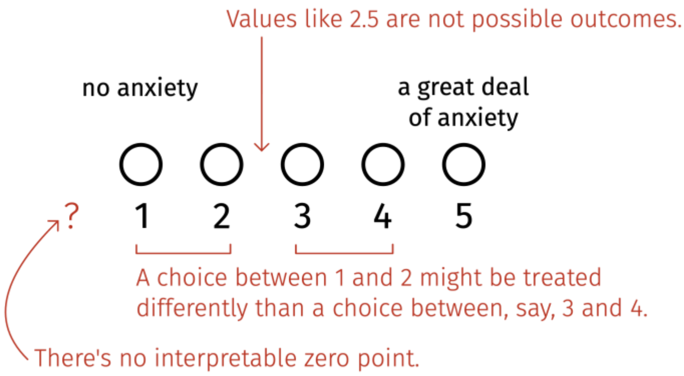
Elizabeth Pankratz, 26 March 2025

Something you won't be able to unsee

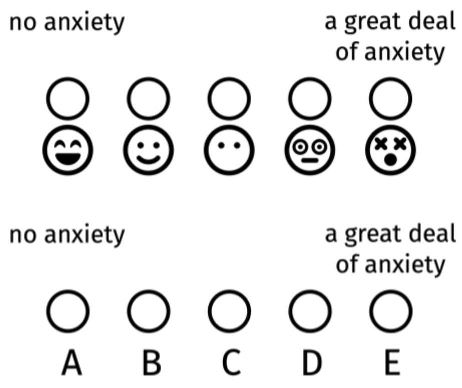


Taking the means of discrete ratings is very common—but a little strange!

Why Likert scale ratings aren't continuous numeric



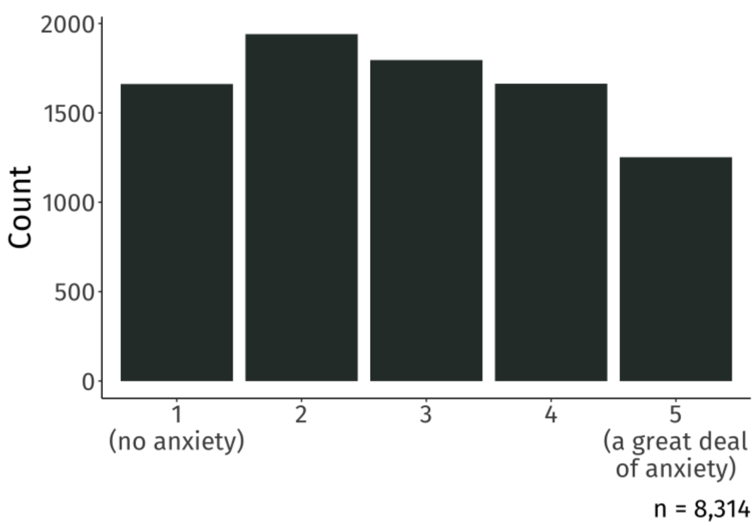
Numbers on a Likert scale are just labels.



The mistake and how you'll avoid it

The mistake	How you'll avoid it
A common R mistake: Letting R treat all variables that look like numbers as continuous numeric.	
An advanced stats mistake: Modelling categorical, ordinal data as if it were numeric.	
A foundational stats mistake: Interpreting a significant *p*-value as evidence that an effect exists in the real world.	

The data: Students' anxiety ratings for "Going to ask my statistics teacher for individual help with material I am having difficulty understanding".



```r
slice(anx, 45:50)
```

```
## # A tibble: 6 × 3
##   unique_id gender         rating
##   <chr>     <chr>           <dbl>
## 1 7d28c303  Female/Woman        4
## 2 7d55383a  Another Gender      4
## 3 8116550a  Female/Woman        1
## 4 83491ff9  Female/Woman        4
## 5 8450f8ad  Male/Man            2
## 6 876547d6  Female/Woman        3
```

`rating` looks like numbers, and R treats it like numbers, as `dbl`.

So it's tempting to manipulate it like numbers.

```r
mean(anx$rating)
```

```
## [1] 2.868054
```

Remember: We are smarter than R is

Store categorical variables as factors.

```r
anx <- anx |>
  mutate(rating = factor(rating))
```

Now it's impossible to incorrectly treat them as if they're numeric!

```r
mean(anx$rating)
```

```
## [1] NA
```

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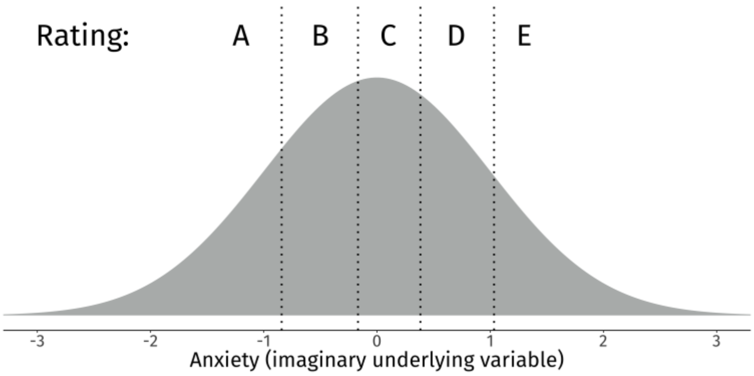
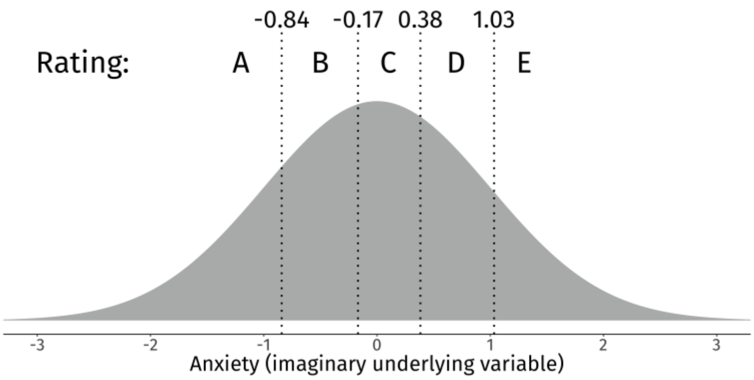
A common R mistake: Letting R treat all variables that look like numbers as continuous numeric. **An advanced stats mistake:** Modelling categorical, ordinal data as if it were numeric. **A foundational stats mistake:** Interpreting a significant *p*-value as evidence that an effect exists in the real world.	When a variable comes from a Likert scale, tell R it's categorical using `factor()`.

What ordinal regression models do

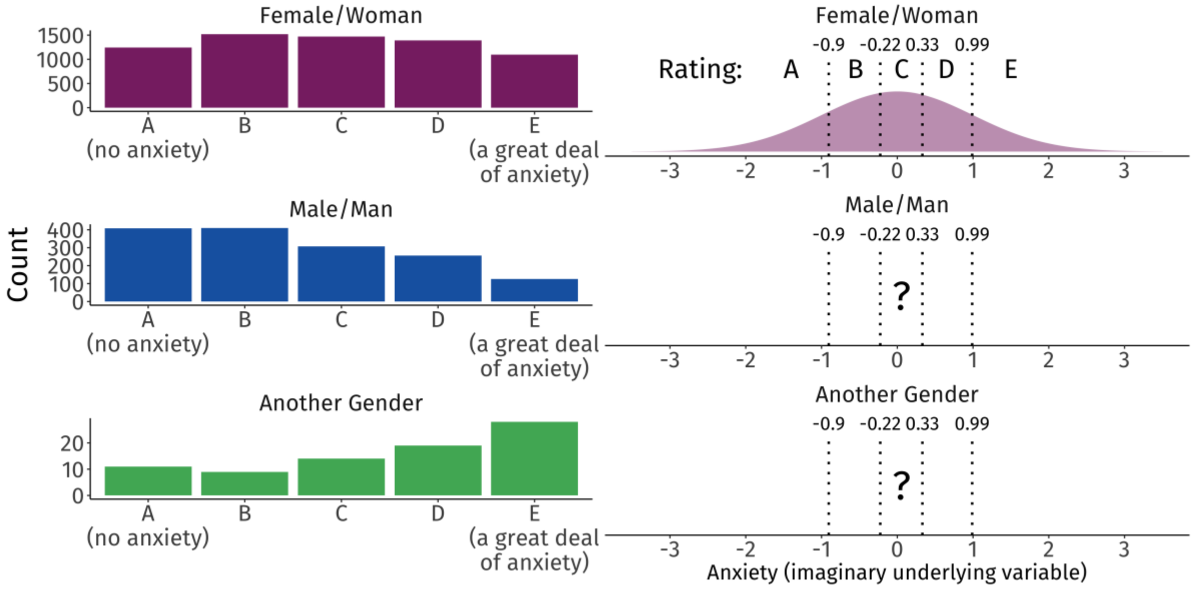


Fit ordinal regression models with `polr()`

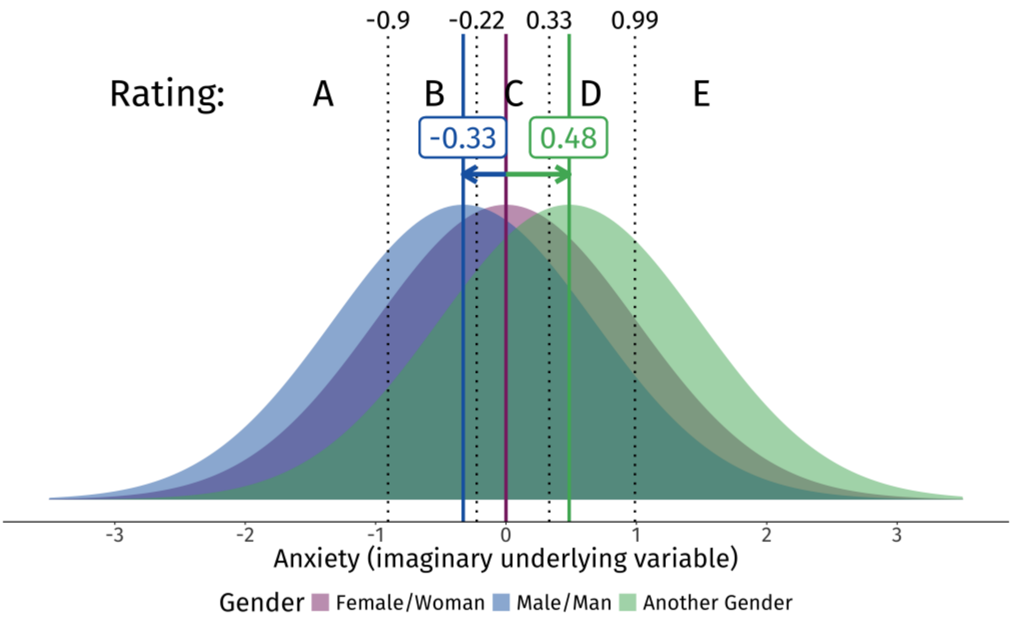
```
library(MASS)          # MASS contains the polr() function

anx_fit1 <- polr(
  rating ~ 1,          # intercept-only model, to start
  data = anx,
  Hess = TRUE, method = 'probit'   # ask me in the Q+A!
)

summary(anx_fit1)

## Intercepts:
##      Value    Std. Error t value
## 1|2  -0.8420   0.0157    -53.7268
## 2|3  -0.1678   0.0138    -12.1462
## 3|4   0.3833   0.0141     27.1512
## 4|5   1.0339   0.0168     61.6193
```



How does a student’s gender affect ratings for “Going to ask my statistics teacher for individual help with material I am having difficulty understanding”?



[don’t turn the page until after the activity!]



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A common R mistake: Letting R treat all variables that look like numbers as continuous numeric.	When a variable comes from a Likert scale, tell R it's categorical using `factor()`.
An advanced stats mistake: Modelling categorical, ordinal data as if it were numeric.	Apply and interpret ordinal regression models (e.g., `polr()` from `MASS`).
A foundational stats mistake: Interpreting a significant *p*-value as evidence that an effect exists in the real world.	

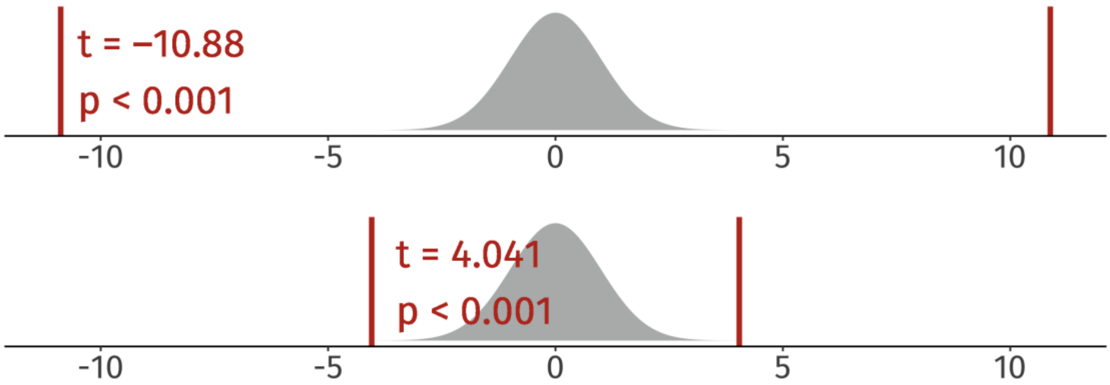
Are the effects of `gender` significant?

```
summary(anx_fit2)
```

```
## Coefficients:
##                          Value Std. Error t value
## genderMale/Man         -0.3280    0.03015 -10.880
## genderAnother Gender    0.4846    0.11992   4.041
```

No *p*-values in the model summary.

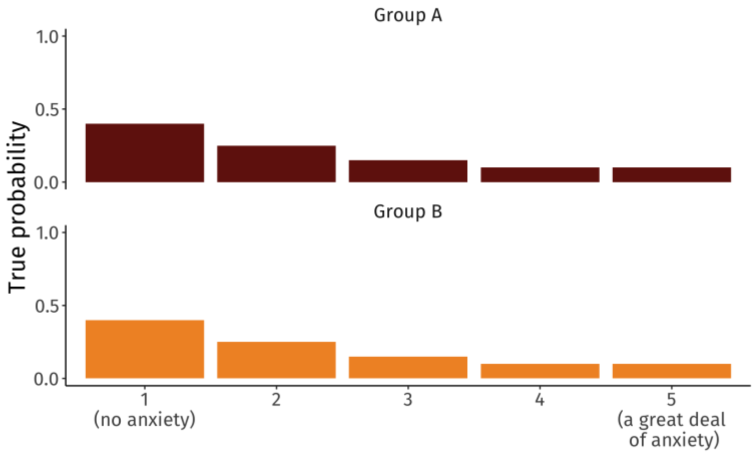
But it's common practice to compare these *t*-values to a standard normal distribution.



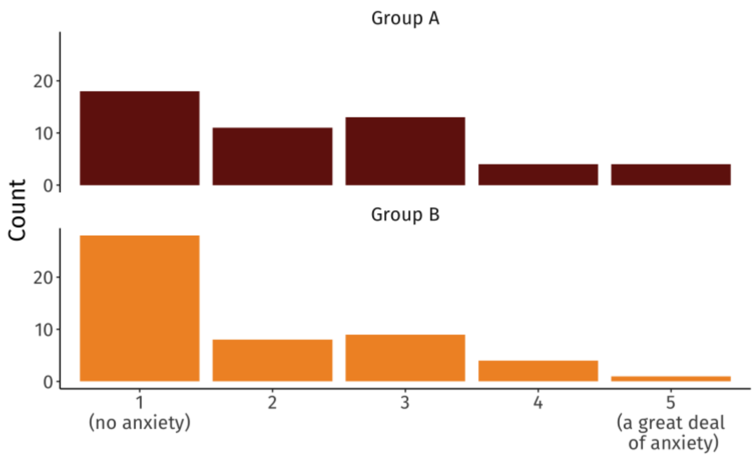
Why don’t significant *p*-values mean an effect exists?

Because we can also get significant *p*-values when there really is *no* effect.

No difference in the true population:

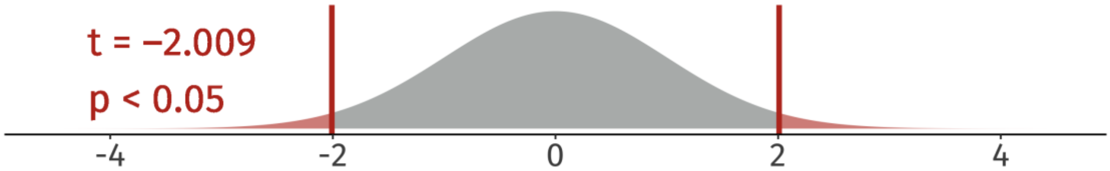


A possible random sample (n = 50 per group):



```r
sim_fit <- polr(rating ~ group, data = simdat, method = 'probit',
Hess = TRUE)
summary(sim_fit)
```

```
## Coefficients:
##                Value Std. Error t value
## groupGroup B -0.4479     0.2229  -2.009
```



So *p* is significant, but in the true population, Group A and Group B were identical!

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An advanced stats mistake: Modelling categorical, ordinal data as if it were numeric.	Apply and interpret ordinal regression models (e.g., `polr()` from `MASS`).
A foundational stats mistake: Interpreting a significant *p*-value as evidence that an effect exists in the real world.	Understand that significant *p*-values can arise even if no effect exists in the real world.

Some really nice resources

- Jamieson's (2004) paper **Likert scales: How to (ab)use them.**
- UCLA Statistical Methods and Data Analytics's web page **Ordinal Logistic Regression.**
- Kurz' (2021) blog post **Notes on the Bayesian cumulative probit.**
- Vasishth and Nicenboim's (2016) paper **Statistical Methods for Linguistic Research: Foundational Ideas – Part I.**
- Gelman and Hill's (2007) book **Data Analysis Using Regression and Multilevel/Hierarchical Models.**

Plot on Slide 2 from

Reeder, P. A., Newport, E. L., & Aslin, R. N. (2017). Distributional learning of subcategories in an artificial grammar: Category generalization and subcategory restrictions. *Journal of Memory and Language*, 97, 17–29.

Data from

Terry, J., Ross, R. M., Nagy, T., Salgado, M., Garrido-Vásquez, P., Sarfo, J. O., Cooper, S., Buttner, A. C., Lima, T. J. S., Öztürk, İ., Akay, N., Santos, F. H., Artemenko, C., Copping, L. T., Elsherif, M. M., Milovanović, I., Cribbie, R. A., Drushlyak, M. G., Swainston, K., … Field, A. P. (2023). Data from an International Multi-Centre Study of Statistics and Mathematics Anxieties and Related Variables in University Students (the SMARVUS Dataset). *Journal of Open Psychology Data*, 11(1), 8.