

# Solutions Stats

## Overview

N.B.: This notebook takes a relatively long time to publish with Quarto.

Some questions raised by my plots for Q10, about solutions (solutions\_plots.qmd):

- Are solution scores by job category the same for all possible pairs of job groups?
- Are non-research staff significantly more likely than other groups to want a learning community?
- Are aspiring contributors significantly more likely than experienced contributors to select solutions related to learning and professional development?
- Are experienced contributors significantly more likely than aspiring contributors to select solutions related to funding?

## Set seed

```
set.seed(42)
```

## Import packages and utilities

```
project_root <- here::here() # requires that you be somewhere in the  
# project directory (not above it)  
# packages  
suppressMessages(source(file.path(project_root, "scripts/packages.R")))  
# functions and objects used across scripts  
suppressMessages(source(file.path(project_root, "scripts/utils.R")))
```

## Load data

```
solutions <- load_qualtrics_data("clean_data/solutions_Q10.tsv")
other_quant <- load_qualtrics_data("clean_data/other_quant.tsv")
```

## Wrangle data

First, let's add a participant ID. We'll need to keep track of these since observations from the same participant are not independent. We'll need to model the participants as a random effect.

```
solutions$participantID <- seq(1, nrow(solutions))
```

Next, remove empty rows, i.e. rows from respondents who didn't receive this question. As with many questions in this survey, we can cut some corners in the code because the question was mandatory. For example, no need to worry about incomplete answers.

```
solutions_and_job <- solutions
solutions_and_job$job_category <- other_quant$job_category
names(solutions_and_job)[length(names(solutions_and_job))] <- "job_category"

nrow(solutions_and_job)
```

```
[1] 332
```

```
# from scripts/utils.R
solutions_and_job <- exclude_empty_rows(solutions_and_job, strict=TRUE)
nrow(solutions_and_job)
```

```
[1] 233
```

Good. We know by now that only 233 participants saw this question.

Here's what we have so far:

```
head(solutions_and_job)
```

	Computing environments		Publicity		Containerization	Documentation	help
1	Very useful	Very useful	Very useful	Very useful	Very useful	Very useful	Very useful
2	Useful	Very useful	Very useful	Very useful	Not very useful		
3	Very useful	Very useful	Very useful	Very useful	Very useful	Very useful	Very useful
4	Not very useful	Useful	Useful	Useful	Very useful	Very useful	Very useful
5	Useful	Not very useful	Not very useful	Useful	Very useful	Very useful	Very useful
7	Not very useful	Not very useful	Very useful	Very useful	Not very useful	Not very useful	Not very useful
	A learning community	Event planning	Mentoring programs		Education		
1	Very useful	Very useful	Very useful	Very useful	Very useful	Very useful	Very useful
2	Useful	Non-applicable	Very useful	Very useful	Very useful	Very useful	Very useful
3	Useful	Useful	Useful	Useful	Not very useful		
4	Not very useful	Useful	Not very useful	Not very useful	Not very useful	Not very useful	Not very useful
5	Not very useful	Not very useful	Useful	Useful	Very useful	Very useful	Very useful
7	Not very useful	Not very useful	Not very useful	Not very useful	Not very useful	Not very useful	Not very useful
	Legal support	Industry partnerships	Sustainability grants				
1	Very useful	Very useful	Very useful	Very useful			
2	Very useful	Useful	Very useful	Very useful			
3	Very useful	Very useful	Very useful	Very useful			
4	Useful	Not very useful	Very useful	Very useful			
5	Useful	Useful	Very useful	Very useful			
7	Very useful	Not very useful	Very useful	Very useful			
	Help finding funding	participantID		job_category			
1	Very useful	1		Faculty			
2	Useful	2		Post-Doc			
3	Very useful	3	Other research staff				
4	Very useful	4		Faculty			
5	Useful	5		Faculty			
7	Very useful	7		Faculty			

Convert to long data, since this makes it easier to remove NAs and is necessary for the statistics.

```
long_data <- solutions_and_job %>%
  pivot_longer(
    cols = -c(participantID, job_category),
    names_to = "solution",
    values_to = "utility"
  )
dim(long_data)
```

[1] 2796 4

```

head(long_data)

# A tibble: 6 x 4
  participantID job_category solution      utility
  <int> <chr>        <chr>          <chr>
1 1 Faculty     Computing environments Very useful
2 1 Faculty     Publicity           Very useful
3 1 Faculty     Containerization   Very useful
4 1 Faculty     Documentation help Very useful
5 1 Faculty     A learning community Very useful
6 1 Faculty     Event planning    Very useful

```

Remove NAs.

```

long_data <- long_data %>%
  filter(!(utility == "Non-applicable"))
dim(long_data)

```

```
[1] 2602    4
```

That removed about 200 rows, out of more than 2000. So less than 10% of the responses were “non-applicable”s.

Make utility an ordered factor. Solution and job category are not inherently ordered, but we’ll make them factors, and the first factor level will be the reference level for that variable. It doesn’t really matter which level we use as the reference level.

```

long_data$utility <- factor(
  long_data$utility,
  levels = c("Not very useful", "Useful", "Very useful"),
  ordered = TRUE
)

long_data$solution <- factor(
  long_data$solution,
  levels = unique(long_data$solution)
)

long_data$job_category <- factor(
  long_data$job_category,

```

```

levels = unique(long_data$job_category)
)

levels(long_data$solution)

[1] "Computing environments" "Publicity"           "Containerization"
[4] "Documentation help"      "A learning community" "Event planning"
[7] "Mentoring programs"     "Education"          "Legal support"
[10] "Industry partnerships"   "Sustainability grants" "Help finding funding"

levels(long_data$job_category)

[1] "Faculty"           "Post-Doc"           "Other research staff"
[4] "Grad Student"      "Non-research Staff" "Undergraduate"

```

Ok, so it looks like our reference levels are computing environments and faculty. That's fine. It doesn't really matter.

## Create candidate models

I'd like to fit a cumulative-logit mixed model, a.k.a. an ordinal regression model, using the `clmm` function from the `ordinal` package. (I am not using `polr` from the `MASS` package because it does not allow random effects.) I know we want to include `participantID` as a random effect, but I'm not really sure how to model solution. I think it would be best to compare different models.

Note that the next few cells take several minutes to run.

### **Model 1: job\_category \* solution interaction**

Here, I'm modeling `job_category` and `solution` as independent fixed effects, and assuming that there is also an effect from the interaction of the two. This way, we get a global slope for `job_category`, a global slope for `solution`, a global slope for the interaction (I think), and a global intercept. Adding `participant` as a random effect allows each participant to have their own deviation from the global intercept.

```

fit1 <- ordinal::clmm(utility ~ job_category * solution +
                       (1 | participantID),
                       data = long_data, link = "logit", Hess = TRUE)

```

```
Warning: (1) Hessian is numerically singular: parameters are not uniquely determined
In addition: Absolute convergence criterion was met, but relative criterion was not met
```

Hm. I get a warning that “Hessian is numerically singular: parameters are not uniquely determined” and “Absolute convergence criterion was met, but relative criterion was not met”. The internet suggests that this might mean that some job\\_category  $\times$  solution combinations have few or zero responses in one of the utility levels, so the full job\\_category \* solution interaction is over-parameterised.

### **Model 2: solution as a random effect, no correlation between participant intercept and job effect**

Here’s another formulation. In this case, solution is another random effect, so we only get one global slope from job\\_category, but each solution intercept (as well as each participant intercept) is allowed to deviate from the global intercept. We assume that across solutions, the deviations in job\\_cateogry effect from the global effect of job\\_category are not correlated with that solution’s intercept’s deviation from the global intercept.

```
fit2 <- ordinal::clmm(utility ~ job_category +
  (1 | solution) +
  (1 | participantID) +
  (0 + job_category | solution),
  data = long_data, link = "logit", Hess = TRUE)
```

Next, we again have 4 terms, like we did in the first model: a global intercept, slopes for job\\_category and solution, and a slope for the interaction. Now, we also estimate the deviance of each of these terms from the global baseline for each participant, and we also estimate the correlations between the deviations for each possible combination of the 4 terms, for each participant. Er, I think. (Helpful cheat sheet: <https://stats.stackexchange.com/questions/13166/r-s-lmer-cheat-sheet>)

This one measures a ton of parameters... ABANDONED; NEVER CONVERGED

```
# fit3 <- ordinal::clmm(utility ~ job_category * solution +      # fixed effects
#                         (0 + job_category*solution | participantID),
#                         data = long_data, link = "logit", Hess = TRUE)
```

All the models seem to be struggling a bit. Let’s explore the data for a moment.

```
# three way cross tabs (xtabs) and flatten the table
# code from: https://ladal.edu.au/tutorials/regression/regression.html
ftable(xtabs(~ job_category + solution + utility, data = long_data))
```

job_category	solution	utility	Not very useful	Useful	Very useful
Faculty	Computing environments	12	17	29	
	Publicity	19	12	24	
	Containerization	19	17	18	
	Documentation help	21	18	17	
	A learning community	21	26	10	
	Event planning	24	19	11	
	Mentoring programs	24	23	8	
	Education	24	21	12	
	Legal support	15	28	12	
	Industry partnerships	18	15	23	
Post-Doc	Sustainability grants	3	10	44	
	Help finding funding	5	13	36	
	Computing environments	4	3	8	
	Publicity	2	6	7	
	Containerization	5	4	6	
	Documentation help	4	6	5	
	A learning community	2	9	4	
	Event planning	5	3	6	
	Mentoring programs	3	7	5	
	Education	2	6	7	
Other research staff	Legal support	2	5	7	
	Industry partnerships	4	3	7	
	Sustainability grants	0	3	12	
	Help finding funding	0	6	9	
	Computing environments	10	11	19	
	Publicity	6	15	16	
	Containerization	14	17	8	
	Documentation help	8	14	16	
	A learning community	8	19	11	
	Event planning	13	14	11	
Grad Student	Mentoring programs	12	13	10	
	Education	11	15	11	
	Legal support	14	11	13	
	Industry partnerships	9	12	14	
	Sustainability grants	3	7	28	
	Help finding funding	2	11	23	
	Computing environments	1	6	19	
	Publicity	2	10	11	
	Containerization	3	10	9	
	Documentation help	5	8	13	
	A learning community	5	9	12	

	Event planning	7	6	11
	Mentoring programs	4	10	12
	Education	5	7	14
	Legal support	3	10	12
	Industry partnerships	3	11	12
	Sustainability grants	0	1	25
	Help finding funding	0	5	20
Non-research Staff	Computing environments	13	32	35
	Publicity	26	33	15
	Containerization	33	24	20
	Documentation help	19	39	26
	A learning community	11	43	31
	Event planning	29	30	16
	Mentoring programs	18	35	24
	Education	21	31	30
	Legal support	13	41	26
	Industry partnerships	23	29	18
	Sustainability grants	8	25	39
	Help finding funding	9	31	32
Undergraduate	Computing environments	0	2	5
	Publicity	0	2	4
	Containerization	1	1	4
	Documentation help	1	3	3
	A learning community	2	1	4
	Event planning	2	2	3
	Mentoring programs	0	4	3
	Education	1	4	2
	Legal support	1	3	2
	Industry partnerships	0	0	7
	Sustainability grants	0	1	5
	Help finding funding	0	2	4

Hm. Indeed, the data are sparse in places, particularly for undergraduates. Perhaps we should combine postdocs + staff researchers, as well as undergrads + grad students.

```
combined <- long_data %>%
  mutate(
    job_category = recode(
      job_category,
      "Post-Doc" = "Postdocs and Staff Researchers",
      "Other research staff" = "Postdocs and Staff Researchers"
    )
  )
```

```

)
combined <- combined %>%
  mutate(
    job_category = recode(
      job_category,
      "Grad Student" = "Students",
      "Undergraduate" = "Students"
    )
  )

```

Now let's run models 1 and 2 again, but with this consolidated dataset.

### **Model 1b: Model 1, but with consolidated data**

```

fit1b <- ordinal::clmm(utility ~ job_category * solution +
  (1 | participantID),
  data = combined, link = "logit", Hess = TRUE)

```

No warning this time, and I feel like it finished faster. My hunch is that this re-labeled dataset will lead to better results.

### **Model 2b: Model 2, but with consolidated data**

```

fit2b <- ordinal::clmm(utility ~ job_category +
  (1 | solution) +
  (1 | participantID) +
  (0 + job_category | solution),
  data = combined, link = "logit", Hess = TRUE)

```

So, those are two fairly complex models that I think capture the important variation. Let's compare them to some simpler models.

### **Model 3: No job category**

Let's make a null model where job category doesn't matter. (Using the consolidated data)

```
fit3 <- ordinal::clmm(utility ~ solution +
  (1 | participantID),
  data = combined, link = "logit", Hess = TRUE)
```

### Model 4: No solution category

How about a model where solution doesn't matter?

```
fit4 <- ordinal::clmm(utility ~ job_category +
  (1 | participantID),
  data = combined, link = "logit", Hess = TRUE)
```

### Model 5: job\_category + solution

In this minimal model, we include job\_category + solution, but without any interaction. This model says that we can predict the rating by simply adding the effect of job category and the effect of solution, with no additional effect from combining a particular job category with a particular solution.

```
fit5 <- ordinal::clmm(utility ~ job_category + solution +
  (1 | participantID),
  data = combined, link = "logit", Hess = TRUE)
```

### Model 6: no random effects

Do we really need to account for participants' individual baselines?

```
# note clm function bc clmm is for mixed models
fit6 <- ordinal::clm(utility ~ job_category * solution,
  data = combined, link = "logit", Hess = TRUE)
```

## Compare models

```

models <- list(
  "fit1"=fit1, # job_category * solution, sparser data
  "fit2"=fit2, # solution as random effect, sparser data
  "fit1b"=fit1b, # job_category * solution, denser data
  "fit2b"=fit2b, # solution as random effect, denser data
  "fit3"=fit3, # Null model: no job
  "fit4"=fit4, # Null model: no solution
  "fit5"=fit5, # Null model: no interaction
  "fit6"=fit6 # Null model: no participants
)

```

First, let's get a general sense of goodness-of-fit by looking at the AICs. You're not supposed to compare AICs for models fit to different data sets (models 1 and 2 are using the sparser data), but since I've only changed the job\_category labels, but not the observations or the number of observations, I think this is ok.

```
sapply(models, function(x) round(stats::AIC(x)))
```

	fit1	fit2	fit1b	fit2b	fit3	fit4	fit5	fit6
	4826	4847	4802	4827	4836	5094	4822	5348

The AICs for all the models are fairly similar, except in two cases: #4, where solution isn't does't matter, and job\_category alone influences the response, and #6, where participant ID doesn't matter. Both of these make sense. Model 5, where job category and solution have no interaction, does fairly well. Maybe job-solution interactions are subtle.

Model 1b looks the best. According to the internet, a delta AIC of more than ten is pretty substantial, and here we have a difference of 20 between the best and second-best.

Let's check the condition number of the Hessian. I don't really understand what this is, but the clmm2 tutorial says that high numbers, say larger than say  $10^4$  or  $10^6$ , indicate poor fit.

```

sapply(models, function(x)
summary(x)$info["cond.H"]
)

```

```
Warning in summary.clmm(x): Variance-covariance matrix of the parameters is not defined
```

```

$fit1.cond.H
[1] "NaN"

$fit2.cond.H
[1] "3.9e+02"

$fit1b.cond.H
[1] "2.8e+03"

$fit2b.cond.H
[1] "2.1e+02"

$fit3.cond.H
[1] "1.5e+02"

$fit4.cond.H
[1] "1.2e+02"

$fit5.cond.H
[1] "1.6e+02"

$fit6.cond.H
[1] "3.9e+03"

```

Okay, depending on my random seed, fit1 either gives a NaN or a high value here. All the other models look decent.

### **Complex models vs null models**

Let's use an anova to compare the two models that scored the best in terms of AIC. Since they also happen to be nested, an anova works here.

```
stats::anova(fit1b, fit5)
```

Likelihood ratio tests of cumulative link models:

```

formula:                                         link: threshold:
fit5  utility ~ job_category + solution + (1 | participantID) logit flexible
fit1b utility ~ job_category * solution + (1 | participantID) logit flexible

no.par    AIC   logLik LR.stat df Pr(>Chisq)

```

```

fit5      17 4822.2 -2394.1
fit1b     50 4802.0 -2351.0  86.199 33  1.221e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

That's a significant p-value. It looks like the interaction term is worth including.

Let's also double-check that participants are worth including.

```
stats::anova(fit1b, fit6)
```

Likelihood ratio tests of cumulative link models:

```

formula:                                         link: threshold:
fit6 utility ~ job_category * solution          logit flexible
fit1b utility ~ job_category * solution + (1 | participantID) logit flexible

no.par    AIC  logLik LR.stat df Pr(>Chisq)
fit6      49 5348.3 -2625.2
fit1b     50 4802.0 -2351.0  548.36  1 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

Yep, definitely want to include those.

Does it matter whether we include job as a variable? Let's compare it to the model with job + solution, without an interaction term.

```
stats::anova(fit3, fit5)
```

Likelihood ratio tests of cumulative link models:

```

formula:                                         link: threshold:
fit3 utility ~ solution + (1 | participantID)      logit flexible
fit5 utility ~ job_category + solution + (1 | participantID) logit flexible

no.par    AIC  logLik LR.stat df Pr(>Chisq)
fit3      14 4836.1 -2404.0
fit5      17 4822.2 -2394.1  19.902  3  0.0001779 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

It appears that job is also significant in explaining the variation in the data.

## More goodness of fit evaluation

How else to evaluate the models? The `ordinal` package provides goodness-of-fit functions `nominal_test` and `scale_test`, but these only work on `clm` objects, not `clmm` objects (mixed models).

Model 2b had a similar AIC as model 5. While I can't compare model 1b and model 2b with `anova`, since they're not nested, I can at least glance at the standard errors of the coefficients, which I think gives me a sense of the precision of the coefficient estimates.

```
summary(fit1b$coefficients)
```

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
-2.15349	-0.68400	-0.05181	-0.07111	0.77637	1.73451

```
summary(fit2b$coefficients)
```

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
-1.38345	0.06018	0.50278	0.30830	0.91531	1.44669

Hm. So `fit1b` had the lowest AIC of all the models and is significantly better at explaining the variation than the equivalent minimal model without an interaction term. However, the coefficients of `fit2b` have smaller SEs than those of `fit1b`.

How about the log likelihoods?

```
LL <- sapply(models, function(x) x$logLik)
# These are a bit hard to read so I am reordering them
LL[order(LL)]
```

fit6	fit4	fit3	fit2b	fit5	fit2	fit1b	fit1
-2625.165	-2541.072	-2404.033	-2396.590	-2394.082	-2393.642	-2350.983	-2339.214

In this case, surprisingly, `fit1` looks best. But according to the interwebs, this can happen just from having more parameters. So I think we should probably only use this to compare models that have the same number of parameters, e.g. `fit3` vs. `fit4`.

So, I find myself in the annoying situation of having several g-o-f tests that don't perfectly agree. However, I'm leaning toward `fit1b`. It had the best AIC and the second-best log-likelihood. The SEs are a little concerning, but I don't think the SEs are a super reliable indicator of g-o-f anyway(?). This model consistently had pretty good g-o-f metrics, and I think it also intuitively makes the most sense.

Let's do one more test. fit6 is the equivalent model to fit1b, but with fixed effects only. Since we can do the nominal\_test and scale\_test on this model, let's try it and see if it sets off any red flags.

```
nominal_test(fit6)
```

Tests of nominal effects

```
formula: utility ~ job_category * solution
          Df  logLik   AIC   LRT Pr(>Chi)
<none>      -2625.2 5348.3
job_category    3 -2619.8 5343.7 10.629  0.01391 *
solution       11 -2613.7 5347.3 23.021  0.01755 *
job_category:solution 47 -2590.8 5373.6 68.737  0.02098 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
scale_test(fit6)
```

```
Warning: (-1) Model failed to converge with max|grad| = 0.000305507 (tol = 1e-06)
In addition: iteration limit reached
```

Tests of scale effects

```
formula: utility ~ job_category * solution
          Df  logLik   AIC   LRT Pr(>Chi)
<none>      -2625.2 5348.3
job_category    3 -2619.8 5343.7 10.629  0.01391 *
solution       11 -2613.7 5347.3 23.021  0.01755 *
job_category:solution 47 -2590.8 5373.6 68.737  0.02098 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Ouch. That's not ideal. Maybe we can proceed with caution, and follow up with a non-parametric test on whatever trends we find? <https://www.fharrell.com/post/po/>

## Interpreting the model results

```
summary(fit1b)
```

Cumulative Link Mixed Model fitted with the Laplace approximation

formula: utility ~ job\_category \* solution + (1 | participantID)  
data: combined

link threshold nobs logLik AIC niter max.grad cond.H  
logit flexible 2602 -2350.98 4801.97 10197(40741) 1.22e-03 2.8e+03

Random effects:

Groups	Name	Variance	Std.Dev.
participantID	(Intercept)	2.097	1.448
Number of groups:	participantID	232	

Coefficients:

	Estimate
job_categoryPostdocs and Staff Researchers	-0.04736
job_categoryStudents	1.66906
job_categoryNon-research Staff	-0.08350
solutionPublicity	-0.66811
solutionContainerization	-1.06243
solutionDocumentation help	-1.21045
solutionA learning community	-1.56910
solutionEvent planning	-1.83275
solutionMentoring programs	-1.93070
solutionEducation	-1.68608
solutionLegal support	-1.18188
solutionIndustry partnerships	-0.68400
solutionSustainability grants	1.73451
solutionHelp finding funding	1.08082
job_categoryPostdocs and Staff Researchers:solutionPublicity	0.78228
job_categoryStudents:solutionPublicity	-0.49909
job_categoryNon-research Staff:solutionPublicity	-0.74669
job_categoryPostdocs and Staff Researchers:solutionContainerization	-0.03388
job_categoryStudents:solutionContainerization	-0.64866
job_categoryNon-research Staff:solutionContainerization	-0.42332
job_categoryPostdocs and Staff Researchers:solutionDocumentation help	0.94435
job_categoryStudents:solutionDocumentation help	-0.35912
job_categoryNon-research Staff:solutionDocumentation help	0.53196
job_categoryPostdocs and Staff Researchers:solutionA learning community	1.02260

job_categoryStudents:solutionA learning community	-0.10889
job_categoryNon-research Staff:solutionA learning community	1.44068
job_categoryPostdocs and Staff Researchers:solutionEvent planning	0.91886
job_categoryStudents:solutionEvent planning	-0.22759
job_categoryNon-research Staff:solutionEvent planning	0.35351
job_categoryPostdocs and Staff Researchers:solutionMentoring programs	1.04164
job_categoryStudents:solutionMentoring programs	0.45731
job_categoryNon-research Staff:solutionMentoring programs	1.24157
job_categoryPostdocs and Staff Researchers:solutionEducation	1.16078
job_categoryStudents:solutionEducation	0.19222
job_categoryNon-research Staff:solutionEducation	1.12431
job_categoryPostdocs and Staff Researchers:solutionLegal support	0.54219
job_categoryStudents:solutionLegal support	-0.35340
job_categoryNon-research Staff:solutionLegal support	0.77637
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships	0.34019
job_categoryStudents:solutionIndustry partnerships	-0.23308
job_categoryNon-research Staff:solutionIndustry partnerships	-0.46161
job_categoryPostdocs and Staff Researchers:solutionSustainability grants	-0.05181
job_categoryStudents:solutionSustainability grants	0.28703
job_categoryNon-research Staff:solutionSustainability grants	-1.21278
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding	-0.02601
job_categoryStudents:solutionHelp finding funding	-0.76619
job_categoryNon-research Staff:solutionHelp finding funding	-1.03639
	Std. Error
job_categoryPostdocs and Staff Researchers	0.49392
job_categoryStudents	0.61824
job_categoryNon-research Staff	0.44158
solutionPublicity	0.40568
solutionContainerization	0.40387
solutionDocumentation help	0.39881
solutionA learning community	0.38854
solutionEvent planning	0.40245
solutionMentoring programs	0.39813
solutionEducation	0.39749
solutionLegal support	0.39142
solutionIndustry partnerships	0.40142
solutionSustainability grants	0.44904
solutionHelp finding funding	0.42632
job_categoryPostdocs and Staff Researchers:solutionPublicity	0.57881
job_categoryStudents:solutionPublicity	0.72018
job_categoryNon-research Staff:solutionPublicity	0.52227
job_categoryPostdocs and Staff Researchers:solutionContainerization	0.57095
job_categoryStudents:solutionContainerization	0.71859

job_categoryNon-research Staff:solutionContainerization	0.52130
job_categoryPostdocs and Staff Researchers:solutionDocumentation help	0.57355
job_categoryStudents:solutionDocumentation help	0.70165
job_categoryNon-research Staff:solutionDocumentation help	0.50803
job_categoryPostdocs and Staff Researchers:solutionA learning community	0.55805
job_categoryStudents:solutionA learning community	0.69278
job_categoryNon-research Staff:solutionA learning community	0.49959
job_categoryPostdocs and Staff Researchers:solutionEvent planning	0.57443
job_categoryStudents:solutionEvent planning	0.71107
job_categoryNon-research Staff:solutionEvent planning	0.51964
job_categoryPostdocs and Staff Researchers:solutionMentoring programs	0.57321
job_categoryStudents:solutionMentoring programs	0.69274
job_categoryNon-research Staff:solutionMentoring programs	0.51079
job_categoryPostdocs and Staff Researchers:solutionEducation	0.57092
job_categoryStudents:solutionEducation	0.69830
job_categoryNon-research Staff:solutionEducation	0.51032
job_categoryPostdocs and Staff Researchers:solutionLegal support	0.56944
job_categoryStudents:solutionLegal support	0.69631
job_categoryNon-research Staff:solutionLegal support	0.50550
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships	0.58203
job_categoryStudents:solutionIndustry partnerships	0.71261
job_categoryNon-research Staff:solutionIndustry partnerships	0.52272
job_categoryPostdocs and Staff Researchers:solutionSustainability grants	0.63964
job_categoryStudents:solutionSustainability grants	0.99068
job_categoryNon-research Staff:solutionSustainability grants	0.56400
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding	0.60587
job_categoryStudents:solutionHelp finding funding	0.77727
job_categoryNon-research Staff:solutionHelp finding funding	0.54190
z value	
job_categoryPostdocs and Staff Researchers	-0.096
job_categoryStudents	2.700
job_categoryNon-research Staff	-0.189
solutionPublicity	-1.647
solutionContainerization	-2.631
solutionDocumentation help	-3.035
solutionA learning community	-4.038
solutionEvent planning	-4.554
solutionMentoring programs	-4.849
solutionEducation	-4.242
solutionLegal support	-3.019
solutionIndustry partnerships	-1.704
solutionSustainability grants	3.863
solutionHelp finding funding	2.535

job_categoryPostdocs and Staff Researchers:solutionPublicity	1.352
job_categoryStudents:solutionPublicity	-0.693
job_categoryNon-research Staff:solutionPublicity	-1.430
job_categoryPostdocs and Staff Researchers:solutionContainerization	-0.059
job_categoryStudents:solutionContainerization	-0.903
job_categoryNon-research Staff:solutionContainerization	-0.812
job_categoryPostdocs and Staff Researchers:solutionDocumentation help	1.646
job_categoryStudents:solutionDocumentation help	-0.512
job_categoryNon-research Staff:solutionDocumentation help	1.047
job_categoryPostdocs and Staff Researchers:solutionA learning community	1.832
job_categoryStudents:solutionA learning community	-0.157
job_categoryNon-research Staff:solutionA learning community	2.884
job_categoryPostdocs and Staff Researchers:solutionEvent planning	1.600
job_categoryStudents:solutionEvent planning	-0.320
job_categoryNon-research Staff:solutionEvent planning	0.680
job_categoryPostdocs and Staff Researchers:solutionMentoring programs	1.817
job_categoryStudents:solutionMentoring programs	0.660
job_categoryNon-research Staff:solutionMentoring programs	2.431
job_categoryPostdocs and Staff Researchers:solutionEducation	2.033
job_categoryStudents:solutionEducation	0.275
job_categoryNon-research Staff:solutionEducation	2.203
job_categoryPostdocs and Staff Researchers:solutionLegal support	0.952
job_categoryStudents:solutionLegal support	-0.508
job_categoryNon-research Staff:solutionLegal support	1.536
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships	0.584
job_categoryStudents:solutionIndustry partnerships	-0.327
job_categoryNon-research Staff:solutionIndustry partnerships	-0.883
job_categoryPostdocs and Staff Researchers:solutionSustainability grants	-0.081
job_categoryStudents:solutionSustainability grants	0.290
job_categoryNon-research Staff:solutionSustainability grants	-2.150
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding	-0.043
job_categoryStudents:solutionHelp finding funding	-0.986
job_categoryNon-research Staff:solutionHelp finding funding	-1.912
	Pr(> z )
job_categoryPostdocs and Staff Researchers	0.923611
job_categoryStudents	0.006941
job_categoryNon-research Staff	0.850023
solutionPublicity	0.099586
solutionContainerization	0.008524
solutionDocumentation help	0.002404
solutionA learning community	5.38e-05
solutionEvent planning	5.26e-06
solutionMentoring programs	1.24e-06

solutionEducation	2.22e-05
solutionLegal support	0.002532
solutionIndustry partnerships	0.088390
solutionSustainability grants	0.000112
solutionHelp finding funding	0.011237
job_categoryPostdocs and Staff Researchers:solutionPublicity	0.176523
job_categoryStudents:solutionPublicity	0.488306
job_categoryNon-research Staff:solutionPublicity	0.152797
job_categoryPostdocs and Staff Researchers:solutionContainerization	0.952681
job_categoryStudents:solutionContainerization	0.366692
job_categoryNon-research Staff:solutionContainerization	0.416773
job_categoryPostdocs and Staff Researchers:solutionDocumentation help	0.099662
job_categoryStudents:solutionDocumentation help	0.608771
job_categoryNon-research Staff:solutionDocumentation help	0.295052
job_categoryPostdocs and Staff Researchers:solutionA learning community	0.066882
job_categoryStudents:solutionA learning community	0.875099
job_categoryNon-research Staff:solutionA learning community	0.003930
job_categoryPostdocs and Staff Researchers:solutionEvent planning	0.109686
job_categoryStudents:solutionEvent planning	0.748914
job_categoryNon-research Staff:solutionEvent planning	0.496319
job_categoryPostdocs and Staff Researchers:solutionMentoring programs	0.069187
job_categoryStudents:solutionMentoring programs	0.509161
job_categoryNon-research Staff:solutionMentoring programs	0.015071
job_categoryPostdocs and Staff Researchers:solutionEducation	0.042035
job_categoryStudents:solutionEducation	0.783112
job_categoryNon-research Staff:solutionEducation	0.027585
job_categoryPostdocs and Staff Researchers:solutionLegal support	0.341017
job_categoryStudents:solutionLegal support	0.611776
job_categoryNon-research Staff:solutionLegal support	0.124579
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships	0.558895
job_categoryStudents:solutionIndustry partnerships	0.743610
job_categoryNon-research Staff:solutionIndustry partnerships	0.377183
job_categoryPostdocs and Staff Researchers:solutionSustainability grants	0.935446
job_categoryStudents:solutionSustainability grants	0.772020
job_categoryNon-research Staff:solutionSustainability grants	0.031531
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding	0.965754
job_categoryStudents:solutionHelp finding funding	0.324256
job_categoryNon-research Staff:solutionHelp finding funding	0.055813
job_categoryPostdocs and Staff Researchers	**
job_categoryStudents	.
job_categoryNon-research Staff	
solutionPublicity	

solutionContainerization	**
solutionDocumentation help	**
solutionA learning community	***
solutionEvent planning	***
solutionMentoring programs	***
solutionEducation	***
solutionLegal support	**
solutionIndustry partnerships	.
solutionSustainability grants	***
solutionHelp finding funding	*
job_categoryPostdocs and Staff Researchers:solutionPublicity	
job_categoryStudents:solutionPublicity	
job_categoryNon-research Staff:solutionPublicity	
job_categoryPostdocs and Staff Researchers:solutionContainerization	
job_categoryStudents:solutionContainerization	
job_categoryNon-research Staff:solutionContainerization	
job_categoryPostdocs and Staff Researchers:solutionDocumentation help	.
job_categoryStudents:solutionDocumentation help	
job_categoryNon-research Staff:solutionDocumentation help	
job_categoryPostdocs and Staff Researchers:solutionA learning community	.
job_categoryStudents:solutionA learning community	
job_categoryNon-research Staff:solutionA learning community	**
job_categoryPostdocs and Staff Researchers:solutionEvent planning	
job_categoryStudents:solutionEvent planning	
job_categoryNon-research Staff:solutionEvent planning	
job_categoryPostdocs and Staff Researchers:solutionMentoring programs	.
job_categoryStudents:solutionMentoring programs	
job_categoryNon-research Staff:solutionMentoring programs	*
job_categoryPostdocs and Staff Researchers:solutionEducation	*
job_categoryStudents:solutionEducation	
job_categoryNon-research Staff:solutionEducation	*
job_categoryPostdocs and Staff Researchers:solutionLegal support	
job_categoryStudents:solutionLegal support	
job_categoryNon-research Staff:solutionLegal support	
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships	
job_categoryStudents:solutionIndustry partnerships	
job_categoryNon-research Staff:solutionIndustry partnerships	
job_categoryPostdocs and Staff Researchers:solutionSustainability grants	
job_categoryStudents:solutionSustainability grants	
job_categoryNon-research Staff:solutionSustainability grants	*
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding	
job_categoryStudents:solutionHelp finding funding	
job_categoryNon-research Staff:solutionHelp finding funding	.

```

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Threshold coefficients:
              Estimate Std. Error z value
Not very useful|Useful -2.1535    0.3461 -6.223
Useful|Very useful     0.1717    0.3425  0.501

```

This is a lot to interpret. I'll do my best. First, let's just at the main effects, i.e. the effects of job category and solution. In the summary above, each job category is compared to Faculty, our job reference level, for the solution Computing environments, our solution reference level. The "Estimate" for job\_categoryStudents is 1.66906, which indicates students have odds of  $e^{1.67}=5.3$  of rating that solution at least one category higher than faculty.

The solution Publicity has a coefficient of -0.66811, indicating that faculty have odds of  $e^{-0.67}=2$  of rating Publicity one level lower than Computing Environments.

The interactions, e.g. job\_categoryPostdocs and Staff Researchers:solutionPublicity, indicate extra log-odds only for that specific job  $\times$  solution pair beyond the two main effects. So in that example, postdocs and staff researchers have an extra log-odds of 0.78228 (odds of  $e^{0.78228}=2.186$ ) of giving publicity a higher rating than computing environments, as compared to faculty.

Interestingly, none of our p-values are super significant for interactions, meaning none of the interactions are really significant on their own. The most significant effects (three asterisks) were all solutions: A learning community (-), Event planning (-), Mentoring programs (-), Education (-), Sustainability grants (+).

So, faculty had significantly higher odds of selecting sustainability grants than computing environments; significantly lower odds of selections education, mentoring, etc. than computing environments.

One job category did get two asterisks:

Coefficients:

	Estimate	Std. Error	z value	Pr(> z )
job_categoryStudents	1.66906	0.61824	2.700	0.006941 **

So, students had somewhat significantly higher odds of selecting computing environments than faculty.

So, painting this with a really broad brush, we might say that responses vary across solutions more than they vary across job categories, at least in the sense that there are more significant differences within faculty than between faculty vs. students.

Since coefficients are hard to interpret, let's get contrasts using the emmeans package. The contrast essentially indicates the difference between two factors' effect sizes. So instead of comparing the coefficients by eye, we can just calculate contrasts that tell us how big the difference is, for each pair of coefficients.

## Estimated marginal means

So, here's my attempt to make sense of a complicated post-hoc exploration of a complicated model. Ordinal regression with the `ordinal` package—and ordinal regression in general, I think—assumes that there is a continuous random variable—a “latent” variable—underlying the categorical outcomes. The category boundaries are then thresholds on the continuous function. The emmeans package gets estimated marginal means from your model: mean outcomes for certain variables while holding other variables constant. The emmeans function can be run in various modes that will change the reported means from the default “latent” scale (whose bounds are arbitrary) to something else. mode = “prob” will report descriptive statistics on the probability distribution of each rating. mode = “mean.class” will report the means of these distributions as probabilities on a scale of 1 to n, where n is the number of outcome categories in your data set. So if you have three outcomes, e.g. not very useful, useful, very useful, and you obtain an average rating of 2.1 for a particular solution with mode=“mean.class”, this means that the (estimated) average rating for that solution was 2.1, or, a teensy bit above “useful”.

I'm using mode=“mean.class” because I find it much easier to interpret an average rating (the sum of the probabilities of each of the three rating categories) than values on the arbitrary latent scale.

N.B.: A warning to keep in mind when using mode=“prob”, and I assume it also applies to mode=“mean.class”: <https://stats.stackexchange.com/questions/615711/why-are-emmip-response-y-axis-numbers-not-probabilities-for-ordinal-regressi#:~:text=There%20are%20several%20ways%20to>, I think we will be okay as long as we include job in the estimate formula?

emmeans also gives you the option to weight the means by averaging over a factor. This handy command lets us see the weights in our model. <https://stats.stackexchange.com/questions/610912/emmeans-weights-for-unbalanced-groups-factors>

```
ref_grid(fit1b)@grid
```

	job_category	solution	.wgt.
1	Faculty Computing environments		58
2	Postdocs and Staff Researchers Computing environments		55
3	Students Computing environments		33
4	Non-research Staff Computing environments		80

5		Faculty	Publicity	55
6	Postdocs and Staff Researchers		Publicity	52
7		Students	Publicity	29
8		Non-research Staff	Publicity	74
9		Faculty	Containerization	54
10	Postdocs and Staff Researchers		Containerization	54
11		Students	Containerization	28
12		Non-research Staff	Containerization	77
13		Faculty	Documentation help	56
14	Postdocs and Staff Researchers		Documentation help	53
15		Students	Documentation help	33
16		Non-research Staff	Documentation help	84
17		Faculty	A learning community	57
18	Postdocs and Staff Researchers		A learning community	53
19		Students	A learning community	33
20		Non-research Staff	A learning community	85
21		Faculty	Event planning	54
22	Postdocs and Staff Researchers		Event planning	52
23		Students	Event planning	31
24		Non-research Staff	Event planning	75
25		Faculty	Mentoring programs	55
26	Postdocs and Staff Researchers		Mentoring programs	50
27		Students	Mentoring programs	33
28		Non-research Staff	Mentoring programs	77
29		Faculty	Education	57
30	Postdocs and Staff Researchers		Education	52
31		Students	Education	33
32		Non-research Staff	Education	82
33		Faculty	Legal support	55
34	Postdocs and Staff Researchers		Legal support	52
35		Students	Legal support	31
36		Non-research Staff	Legal support	80
37		Faculty	Industry partnerships	56
38	Postdocs and Staff Researchers		Industry partnerships	49
39		Students	Industry partnerships	33
40		Non-research Staff	Industry partnerships	70
41		Faculty	Sustainability grants	57
42	Postdocs and Staff Researchers		Sustainability grants	53
43		Students	Sustainability grants	32
44		Non-research Staff	Sustainability grants	72
45		Faculty	Help finding funding	54
46	Postdocs and Staff Researchers		Help finding funding	51
47		Students	Help finding funding	31

It appears that non-research staff are weighted more heavily, and students less so, presumably because there are a lot of observations for that group and not many for the other, respectively.

```
sapply(
  c(
    "Students",
    "Non-research Staff",
    "Postdocs and Staff Researchers",
    "Faculty"
  ),
  function(x) {
    nrow(subset(combined, job_category == x))
  }
)
```

	Students	Non-research Staff
	380	928
Postdocs and Staff Researchers		Faculty
	626	668

### “Global” emms: averaging over job category

First, let’s explore the “overall” ratings with different weighting schemes. I’m not cherry picking here, I’m just trying to understand the options. Let’s calculate estimated marginal means for each solution, while holding job category constant. These will be really rough estimates, since we’re averaging all the job categories, either equally or in proportion to their sample sizes.

(Here’s a somewhat helpful explanation of weights in emmeans: <https://stackoverflow.com/questions/66748520/what-is-the-difference-between-weights-cell-and-weights-proportional-in-r-pa>)

```
# code copied from https://cran.r-project.org/web/packages/emmeans/vignettes/messy-data.html
sapply(c("equal", "prop", "outer", "cells", "flat"), \w
  emmeans(fit1b, ~ solution, weights = w) |> predict() |> head()
```

NOTE: Results may be misleading due to involvement in interactions  
 NOTE: Results may be misleading due to involvement in interactions  
 NOTE: Results may be misleading due to involvement in interactions  
 NOTE: Results may be misleading due to involvement in interactions  
 NOTE: Results may be misleading due to involvement in interactions

	equal	prop	outer	cells	flat
[1,]	1.37546661	1.1934942	1.1934942	1.1935455	1.37546661
[2,]	0.59148638	0.3743983	0.3743983	0.3738146	0.59148638
[3,]	0.03657354	-0.1227918	-0.1227918	-0.1411864	0.03657354
[4,]	0.44431303	0.3475157	0.3475157	0.3487806	0.44431303
[5,]	0.39495919	0.3683255	0.3683255	0.3802930	0.39495919
[6,]	-0.19609423	-0.3253567	-0.3253567	-0.3217714	-0.19609423

We only get two sets of estimates: equal/flat gives us the estimates where all means are given equal weight. Prop, outer, and cells give us another set of estimates, where each prediction is given the weights proportional to sample size. At least, I think that's how it works.

We know from the descriptive statistics and exploratory plots that “a learning community” is more popular among non-research staff than among other groups. So, we expect that if all groups are weighted equally, “a learning community” will be less popular than if we weight the means by sample size.

Hmm. When I try running the command below, to get global solution ratings averaged over job, the command fails when I include mode=“mean.class”. It says no weighting information is available.

```
summary(emmeans(fit1b, ~ solution, weights = "equal", mode = "mean.class")) %>%
  arrange(desc(mean.class))
```

```
Warning in emmeans(fit1b, ~solution, weights = "equal", mode = "mean.class") :
  'weights' requested but no weighting information is available
```

NOTE: Results may be misleading due to involvement in interactions

solution	mean.class	SE	df	asymph.LCL	asymph.UCL
Sustainability grants	2.77	0.0338	Inf	2.70	2.83
Help finding funding	2.63	0.0449	Inf	2.54	2.72
Computing environments	2.45	0.0535	Inf	2.35	2.56
Industry partnerships	2.21	0.0611	Inf	2.09	2.33
Publicity	2.21	0.0616	Inf	2.09	2.33
Documentation help	2.16	0.0625	Inf	2.04	2.28
Legal support	2.16	0.0624	Inf	2.03	2.28
A learning community	2.14	0.0613	Inf	2.02	2.26
Education	2.11	0.0619	Inf	1.99	2.23
Mentoring programs	2.05	0.0613	Inf	1.93	2.17
Containerization	2.01	0.0647	Inf	1.89	2.14
Event planning	1.93	0.0647	Inf	1.80	2.06

```
Results are averaged over the levels of: job_category
Confidence level used: 0.95
```

UPDATE: This was indeed a bug that will be fixed in the next version of emmeans.  
<https://github.com/rvlenth/emmeans/issues/553>

Below is Russ Lenth's suggested workaround to "manually" calculate weighted means on the mean.class scale.

```
# Just for fun -- will not report
emm.pr <- emmeans(fit1b, ~ utility|solution, weights = "prop", mode = "prob")
contrast(emm.pr, list(mc = 1:3)) |> confint(by=NULL) |> arrange(desc(estimate))
```

contrast	solution	estimate	SE	df	asymp.LCL	asymp.UCL
mc	Sustainability grants	2.72	0.0408	Inf	2.64	2.80
mc	Help finding funding	2.58	0.0491	Inf	2.48	2.67
mc	Computing environments	2.40	0.0559	Inf	2.29	2.51
mc	Industry partnerships	2.14	0.0610	Inf	2.02	2.26
mc	A learning community	2.13	0.0577	Inf	2.02	2.25
mc	Legal support	2.13	0.0596	Inf	2.01	2.25
mc	Publicity	2.13	0.0598	Inf	2.01	2.25
mc	Documentation help	2.12	0.0595	Inf	2.01	2.24
mc	Education	2.08	0.0594	Inf	1.96	2.19
mc	Mentoring programs	2.01	0.0592	Inf	1.89	2.12
mc	Containerization	1.96	0.0613	Inf	1.83	2.08
mc	Event planning	1.88	0.0609	Inf	1.76	2.00

```
Results are averaged over the levels of: job_category
Confidence level used: 0.95
```

```
# Use this one for supplement
emm.eq <- emmeans(fit1b, ~ utility|solution, weights = "equal", mode = "prob")
emm.eq.res <- contrast(emm.eq, list(mc = 1:3)) |> confint(by=NULL) |> arrange(desc(estimate))
emm.eq.res
```

contrast	solution	estimate	SE	df	asymp.LCL	asymp.UCL
mc	Sustainability grants	2.77	0.0338	Inf	2.70	2.83
mc	Help finding funding	2.63	0.0449	Inf	2.54	2.72
mc	Computing environments	2.45	0.0535	Inf	2.35	2.56
mc	Industry partnerships	2.21	0.0611	Inf	2.09	2.33

mc	Publicity	2.21	0.0616	Inf	2.09	2.33
mc	Documentation help	2.16	0.0625	Inf	2.04	2.28
mc	Legal support	2.16	0.0624	Inf	2.03	2.28
mc	A learning community	2.14	0.0613	Inf	2.02	2.26
mc	Education	2.11	0.0619	Inf	1.99	2.23
mc	Mentoring programs	2.05	0.0613	Inf	1.93	2.17
mc	Containerization	2.01	0.0647	Inf	1.89	2.14
mc	Event planning	1.93	0.0647	Inf	1.80	2.06

Results are averaged over the levels of: job\_category

Confidence level used: 0.95

```
# From utils.R
write_df_to_file(emm.eq.res, "supplementary_tables/solns_global_mean_ratings.tsv")
```

When we use the default weighting of “equal”, “A learning community” is #8, but with “prop” weighting, it rises to #5. This makes sense, as discussed above.

It’s not great to average over a factor that we’ve already established is important. I’ll report it, but with big caveats in the text. I like prop weighting since this is an observational study—the samples are not equal. For lack of a better idea (e.g. weighting groups by expected population size), we are “correcting” for the differences in sample size, so that all groups get equal weight.

### Emms for each solution, for each job category

Here, we get the mean ratings for each job, ordered by job.

```
all_means <- emmeans(fit1b, ~ solution | job_category, mode="mean.class")
summary(all_means) %>%
  arrange(desc(mean.class))
```

job_category = Faculty:	solution	mean.class	SE	df	asymp.LCL	asymp.UCL
Sustainability grants		2.81	0.0648	Inf	2.68	2.93
Help finding funding		2.67	0.0898	Inf	2.50	2.85
Computing environments		2.35	0.1170	Inf	2.12	2.58
Publicity		2.12	0.1250	Inf	1.87	2.36
Industry partnerships		2.11	0.1240	Inf	1.87	2.35
Containerization		1.97	0.1250	Inf	1.73	2.22
Legal support		1.93	0.1190	Inf	1.70	2.16

Documentation help	1.92	0.1220	Inf	1.68	2.16
A learning community	1.79	0.1160	Inf	1.56	2.02
Education	1.75	0.1190	Inf	1.52	1.98
Event planning	1.70	0.1190	Inf	1.47	1.93
Mentoring programs	1.66	0.1150	Inf	1.44	1.89
 job_category = Postdocs and Staff Researchers:					
solution	mean.class	SE	df	asymp.LCL	asymp.UCL
Sustainability grants	2.79	0.0699	Inf	2.65	2.93
Help finding funding	2.66	0.0929	Inf	2.47	2.84
Publicity	2.38	0.1180	Inf	2.14	2.61
Computing environments	2.34	0.1230	Inf	2.10	2.58
Documentation help	2.24	0.1230	Inf	2.00	2.49
Industry partnerships	2.22	0.1280	Inf	1.97	2.47
Education	2.15	0.1240	Inf	1.91	2.40
A learning community	2.14	0.1210	Inf	1.91	2.38
Legal support	2.11	0.1260	Inf	1.86	2.36
Mentoring programs	2.02	0.1270	Inf	1.77	2.27
Event planning	2.01	0.1250	Inf	1.76	2.26
Containerization	1.94	0.1220	Inf	1.70	2.18
 job_category = Students:					
solution	mean.class	SE	df	asymp.LCL	asymp.UCL
Sustainability grants	2.97	0.0250	Inf	2.92	3.02
Help finding funding	2.84	0.0743	Inf	2.70	2.99
Computing environments	2.80	0.0877	Inf	2.62	2.97
Industry partnerships	2.59	0.1310	Inf	2.33	2.85
Publicity	2.52	0.1440	Inf	2.23	2.80
Mentoring programs	2.42	0.1450	Inf	2.13	2.70
Education	2.41	0.1490	Inf	2.12	2.70
Legal support	2.40	0.1500	Inf	2.10	2.69
Documentation help	2.39	0.1510	Inf	2.09	2.68
A learning community	2.35	0.1530	Inf	2.05	2.65
Containerization	2.34	0.1610	Inf	2.02	2.66
Event planning	2.22	0.1640	Inf	1.89	2.54
 job_category = Non-research Staff:					
solution	mean.class	SE	df	asymp.LCL	asymp.UCL
Sustainability grants	2.50	0.0922	Inf	2.32	2.68
Help finding funding	2.34	0.0992	Inf	2.15	2.53
Computing environments	2.32	0.0965	Inf	2.14	2.51
A learning community	2.28	0.0930	Inf	2.10	2.46
Legal support	2.18	0.0973	Inf	1.99	2.37

Education	2.13	0.0986	Inf	1.93	2.32
Documentation help	2.08	0.0964	Inf	1.89	2.27
Mentoring programs	2.08	0.0991	Inf	1.88	2.27
Industry partnerships	1.91	0.1050	Inf	1.71	2.12
Publicity	1.82	0.1010	Inf	1.62	2.01
Event planning	1.79	0.1010	Inf	1.60	1.99
Containerization	1.79	0.1010	Inf	1.59	1.99

Confidence level used: 0.95

The same data, but ordered by solution.

```
all_means2 <- emmeans(fit1b, ~ job_category | solution, mode="mean.class")
summary(all_means2) %>%
  arrange(desc(mean.class))
```

solution = Computing environments:

job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.80	0.0877	Inf	2.62	2.97
Faculty	2.35	0.1170	Inf	2.12	2.58
Postdocs and Staff Researchers	2.34	0.1230	Inf	2.10	2.58
Non-research Staff	2.32	0.0965	Inf	2.14	2.51

solution = Publicity:

job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.52	0.1440	Inf	2.23	2.80
Postdocs and Staff Researchers	2.38	0.1180	Inf	2.14	2.61
Faculty	2.12	0.1250	Inf	1.87	2.36
Non-research Staff	1.82	0.1010	Inf	1.62	2.01

solution = Containerization:

job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.34	0.1610	Inf	2.02	2.66
Faculty	1.97	0.1250	Inf	1.73	2.22
Postdocs and Staff Researchers	1.94	0.1220	Inf	1.70	2.18
Non-research Staff	1.79	0.1010	Inf	1.59	1.99

solution = Documentation help:

job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.39	0.1510	Inf	2.09	2.68
Postdocs and Staff Researchers	2.24	0.1230	Inf	2.00	2.49
Non-research Staff	2.08	0.0964	Inf	1.89	2.27

Faculty	1.92	0.1220	Inf	1.68	2.16
<b>solution = A learning community:</b>					
job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.35	0.1530	Inf	2.05	2.65
Non-research Staff	2.28	0.0930	Inf	2.10	2.46
Postdocs and Staff Researchers	2.14	0.1210	Inf	1.91	2.38
Faculty	1.79	0.1160	Inf	1.56	2.02
<b>solution = Event planning:</b>					
job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.22	0.1640	Inf	1.89	2.54
Postdocs and Staff Researchers	2.01	0.1250	Inf	1.76	2.26
Non-research Staff	1.79	0.1010	Inf	1.60	1.99
Faculty	1.70	0.1190	Inf	1.47	1.93
<b>solution = Mentoring programs:</b>					
job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.42	0.1450	Inf	2.13	2.70
Non-research Staff	2.08	0.0991	Inf	1.88	2.27
Postdocs and Staff Researchers	2.02	0.1270	Inf	1.77	2.27
Faculty	1.66	0.1150	Inf	1.44	1.89
<b>solution = Education:</b>					
job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.41	0.1490	Inf	2.12	2.70
Postdocs and Staff Researchers	2.15	0.1240	Inf	1.91	2.40
Non-research Staff	2.13	0.0986	Inf	1.93	2.32
Faculty	1.75	0.1190	Inf	1.52	1.98
<b>solution = Legal support:</b>					
job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.40	0.1500	Inf	2.10	2.69
Non-research Staff	2.18	0.0973	Inf	1.99	2.37
Postdocs and Staff Researchers	2.11	0.1260	Inf	1.86	2.36
Faculty	1.93	0.1190	Inf	1.70	2.16
<b>solution = Industry partnerships:</b>					
job_category	mean.class	SE	df	asymp.LCL	asymp.UCL
Students	2.59	0.1310	Inf	2.33	2.85
Postdocs and Staff Researchers	2.22	0.1280	Inf	1.97	2.47
Faculty	2.11	0.1240	Inf	1.87	2.35
Non-research Staff	1.91	0.1050	Inf	1.71	2.12

```

solution = Sustainability grants:
job_category           mean.class      SE   df asymp.LCL asymp.UCL
Students                  2.97 0.0250 Inf    2.92    3.02
Faculty                   2.81 0.0648 Inf    2.68    2.93
Postdocs and Staff Researchers 2.79 0.0699 Inf    2.65    2.93
Non-research Staff        2.50 0.0922 Inf    2.32    2.68

solution = Help finding funding:
job_category           mean.class      SE   df asymp.LCL asymp.UCL
Students                  2.84 0.0743 Inf    2.70    2.99
Faculty                   2.67 0.0898 Inf    2.50    2.85
Postdocs and Staff Researchers 2.66 0.0929 Inf    2.47    2.84
Non-research Staff        2.34 0.0992 Inf    2.15    2.53

Confidence level used: 0.95

```

## Pairwise comparisons

Here, we are looking at all possible pairwise comparisons. Again, we are no longer averaging over job category.

I'm using Russ's workaround again because I was playing around with different weighting schemes. In the end, I decided on equal, the default.

```

emm.eq.job <- emmeans(fit1b, ~ utility | job_category * solution, mode = "prob")
emm.eq.job.res <- contrast(emm.eq.job, list(mc=1:3))
emm.eq.job.res |> confint(by=NULL)

```

contrast	job_category	solution	estimate	SE
mc	Faculty	Computing environments	2.35	0.1170
mc	Postdocs and Staff Researchers	Computing environments	2.34	0.1230
mc	Students	Computing environments	2.80	0.0877
mc	Non-research Staff	Computing environments	2.32	0.0965
mc	Faculty	Publicity	2.12	0.1250
mc	Postdocs and Staff Researchers	Publicity	2.38	0.1180
mc	Students	Publicity	2.52	0.1440
mc	Non-research Staff	Publicity	1.82	0.1010
mc	Faculty	Containerization	1.97	0.1250
mc	Postdocs and Staff Researchers	Containerization	1.94	0.1220
mc	Students	Containerization	2.34	0.1610
mc	Non-research Staff	Containerization	1.79	0.1010

mc	Faculty	Documentation help	1.92	0.1220
mc	Postdocs and Staff Researchers	Documentation help	2.24	0.1230
mc	Students	Documentation help	2.39	0.1510
mc	Non-research Staff	Documentation help	2.08	0.0964
mc	Faculty	A learning community	1.79	0.1160
mc	Postdocs and Staff Researchers	A learning community	2.14	0.1210
mc	Students	A learning community	2.35	0.1530
mc	Non-research Staff	A learning community	2.28	0.0930
mc	Faculty	Event planning	1.70	0.1190
mc	Postdocs and Staff Researchers	Event planning	2.01	0.1250
mc	Students	Event planning	2.22	0.1640
mc	Non-research Staff	Event planning	1.79	0.1010
mc	Faculty	Mentoring programs	1.66	0.1150
mc	Postdocs and Staff Researchers	Mentoring programs	2.02	0.1270
mc	Students	Mentoring programs	2.42	0.1450
mc	Non-research Staff	Mentoring programs	2.08	0.0991
mc	Faculty	Education	1.75	0.1190
mc	Postdocs and Staff Researchers	Education	2.15	0.1240
mc	Students	Education	2.41	0.1490
mc	Non-research Staff	Education	2.13	0.0986
mc	Faculty	Legal support	1.93	0.1190
mc	Postdocs and Staff Researchers	Legal support	2.11	0.1260
mc	Students	Legal support	2.40	0.1500
mc	Non-research Staff	Legal support	2.18	0.0973
mc	Faculty	Industry partnerships	2.11	0.1240
mc	Postdocs and Staff Researchers	Industry partnerships	2.22	0.1280
mc	Students	Industry partnerships	2.59	0.1310
mc	Non-research Staff	Industry partnerships	1.91	0.1050
mc	Faculty	Sustainability grants	2.81	0.0648
mc	Postdocs and Staff Researchers	Sustainability grants	2.79	0.0699
mc	Students	Sustainability grants	2.97	0.0250
mc	Non-research Staff	Sustainability grants	2.50	0.0922
mc	Faculty	Help finding funding	2.67	0.0898
mc	Postdocs and Staff Researchers	Help finding funding	2.66	0.0929
mc	Students	Help finding funding	2.84	0.0743
mc	Non-research Staff	Help finding funding	2.34	0.0992
df asymp.LCL asymp.UCL				
Inf	2.12	2.58		
Inf	2.10	2.58		
Inf	2.62	2.97		
Inf	2.14	2.51		
Inf	1.87	2.36		
Inf	2.14	2.61		

Inf	2.23	2.80
Inf	1.62	2.01
Inf	1.73	2.22
Inf	1.70	2.18
Inf	2.02	2.66
Inf	1.59	1.99
Inf	1.68	2.16
Inf	2.00	2.49
Inf	2.09	2.68
Inf	1.89	2.27
Inf	1.56	2.02
Inf	1.91	2.38
Inf	2.05	2.65
Inf	2.10	2.46
Inf	1.47	1.93
Inf	1.76	2.26
Inf	1.89	2.54
Inf	1.60	1.99
Inf	1.44	1.89
Inf	1.77	2.27
Inf	2.13	2.70
Inf	1.88	2.27
Inf	1.52	1.98
Inf	1.91	2.40
Inf	2.12	2.70
Inf	1.93	2.32
Inf	1.70	2.16
Inf	1.86	2.36
Inf	2.10	2.69
Inf	1.99	2.37
Inf	1.87	2.35
Inf	1.97	2.47
Inf	2.33	2.85
Inf	1.71	2.12
Inf	2.68	2.93
Inf	2.65	2.93
Inf	2.92	3.02
Inf	2.32	2.68
Inf	2.50	2.85
Inf	2.47	2.84
Inf	2.70	2.99
Inf	2.15	2.53

Confidence level used: 0.95

Here, we get all pairwise comparisons, with p-values. The “estimate” here is the difference between the estimated means above.

```
by_job <- summary(  
  pairs(emm.eq.job.res, by = "job_category"),  
  infer = TRUE # infer CIs  
)  
by_job
```

job_category = Faculty: contrast	estimate	SE	df
mc Computing environments - mc Publicity	0.23622	0.1430	Inf
mc Computing environments - mc Containerization	0.37914	0.1420	Inf
mc Computing environments - mc Documentation help	0.43280	0.1400	Inf
mc Computing environments - mc A learning community	0.56189	0.1350	Inf
mc Computing environments - mc Event planning	0.65494	0.1380	Inf
mc Computing environments - mc Mentoring programs	0.68885	0.1360	Inf
mc Computing environments - mc Education	0.60345	0.1380	Inf
mc Computing environments - mc Legal support	0.42245	0.1370	Inf
mc Computing environments - mc Industry partnerships	0.24196	0.1410	Inf
mc Computing environments - mc Sustainability grants	-0.45350	0.1170	Inf
mc Computing environments - mc Help finding funding	-0.32175	0.1250	Inf
mc Publicity - mc Containerization	0.14292	0.1470	Inf
mc Publicity - mc Documentation help	0.19659	0.1450	Inf
mc Publicity - mc A learning community	0.32568	0.1400	Inf
mc Publicity - mc Event planning	0.41872	0.1430	Inf
mc Publicity - mc Mentoring programs	0.45263	0.1410	Inf
mc Publicity - mc Education	0.36723	0.1430	Inf
mc Publicity - mc Legal support	0.18624	0.1420	Inf
mc Publicity - mc Industry partnerships	0.00574	0.1460	Inf
mc Publicity - mc Sustainability grants	-0.68972	0.1250	Inf
mc Publicity - mc Help finding funding	-0.55796	0.1320	Inf
mc Containerization - mc Documentation help	0.05366	0.1440	Inf
mc Containerization - mc A learning community	0.18276	0.1400	Inf
mc Containerization - mc Event planning	0.27580	0.1430	Inf
mc Containerization - mc Mentoring programs	0.30971	0.1410	Inf
mc Containerization - mc Education	0.22431	0.1420	Inf
mc Containerization - mc Legal support	0.04332	0.1420	Inf
mc Containerization - mc Industry partnerships	-0.13718	0.1460	Inf
mc Containerization - mc Sustainability grants	-0.83264	0.1240	Inf

mc Containerization - mc Help finding funding	-0.70088	0.1310	Inf
mc Documentation help - mc A learning community	0.12909	0.1380	Inf
mc Documentation help - mc Event planning	0.22214	0.1410	Inf
mc Documentation help - mc Mentoring programs	0.25605	0.1390	Inf
mc Documentation help - mc Education	0.17065	0.1400	Inf
mc Documentation help - mc Legal support	-0.01035	0.1400	Inf
mc Documentation help - mc Industry partnerships	-0.19084	0.1440	Inf
mc Documentation help - mc Sustainability grants	-0.88630	0.1220	Inf
mc Documentation help - mc Help finding funding	-0.75455	0.1290	Inf
mc A learning community - mc Event planning	0.09305	0.1360	Inf
mc A learning community - mc Mentoring programs	0.12696	0.1340	Inf
mc A learning community - mc Education	0.04156	0.1350	Inf
mc A learning community - mc Legal support	-0.13944	0.1350	Inf
mc A learning community - mc Industry partnerships	-0.31994	0.1390	Inf
mc A learning community - mc Sustainability grants	-1.01539	0.1160	Inf
mc A learning community - mc Help finding funding	-0.88364	0.1240	Inf
mc Event planning - mc Mentoring programs	0.03391	0.1360	Inf
mc Event planning - mc Education	-0.05149	0.1380	Inf
mc Event planning - mc Legal support	-0.23249	0.1380	Inf
mc Event planning - mc Industry partnerships	-0.41298	0.1420	Inf
mc Event planning - mc Sustainability grants	-1.10844	0.1200	Inf
mc Event planning - mc Help finding funding	-0.97669	0.1270	Inf
mc Mentoring programs - mc Education	-0.08540	0.1360	Inf
mc Mentoring programs - mc Legal support	-0.26640	0.1360	Inf
mc Mentoring programs - mc Industry partnerships	-0.44689	0.1400	Inf
mc Mentoring programs - mc Sustainability grants	-1.14235	0.1160	Inf
mc Mentoring programs - mc Help finding funding	-1.01060	0.1240	Inf
mc Education - mc Legal support	-0.18100	0.1380	Inf
mc Education - mc Industry partnerships	-0.36149	0.1420	Inf
mc Education - mc Sustainability grants	-1.05695	0.1190	Inf
mc Education - mc Help finding funding	-0.92520	0.1260	Inf
mc Legal support - mc Industry partnerships	-0.18049	0.1410	Inf
mc Legal support - mc Sustainability grants	-0.87595	0.1190	Inf
mc Legal support - mc Help finding funding	-0.74420	0.1260	Inf
mc Industry partnerships - mc Sustainability grants	-0.69546	0.1230	Inf
mc Industry partnerships - mc Help finding funding	-0.56370	0.1300	Inf
mc Sustainability grants - mc Help finding funding	0.13175	0.0962	Inf
asymp.LCL			
asymp.UCL			
z.ratio			
p.value			
-0.22988	0.70231	1.656	0.8878
-0.08558	0.84386	2.666	0.2433
-0.02510	0.89070	3.089	0.0849
0.12029	1.00349	4.158	0.0019
0.20288	1.10700	4.735	0.0001

0.24467	1.13303	5.068	<.0001
0.15348	1.05342	4.383	0.0007
-0.02656	0.87146	3.075	0.0883
-0.21914	0.70305	1.715	0.8618
-0.83629	-0.07071	-3.872	0.0061
-0.72992	0.08643	-2.576	0.2933
-0.33727	0.62311	0.973	0.9982
-0.27689	0.67006	1.357	0.9713
-0.13345	0.78480	2.318	0.4634
-0.04988	0.88732	2.920	0.1336
-0.00909	0.91436	3.204	0.0608
-0.10032	0.83478	2.567	0.2987
-0.27892	0.65139	1.308	0.9783
-0.47260	0.48408	0.039	1.0000
-1.09721	-0.28222	-5.531	<.0001
-0.98793	-0.12800	-4.241	0.0013
-0.41846	0.52579	0.371	1.0000
-0.27471	0.64022	1.306	0.9786
-0.19076	0.74237	1.932	0.7393
-0.14988	0.76931	2.202	0.5479
-0.24104	0.68966	1.575	0.9182
-0.41962	0.50625	0.306	1.0000
-0.61350	0.33914	-0.941	0.9987
-1.23945	-0.42582	-6.689	<.0001
-1.12970	-0.27207	-5.341	<.0001
-0.32113	0.57932	0.937	0.9987
-0.23742	0.68170	1.580	0.9167
-0.19683	0.70892	1.848	0.7914
-0.28826	0.62955	1.215	0.9879
-0.46685	0.44615	-0.074	1.0000
-0.66074	0.27906	-1.327	0.9757
-1.28524	-0.48737	-7.260	<.0001
-1.17602	-0.33308	-5.851	<.0001
-0.35088	0.53698	0.685	0.9999
-0.30944	0.56335	0.951	0.9986
-0.40053	0.48365	0.307	1.0000
-0.58077	0.30189	-1.033	0.9970
-0.77466	0.13479	-2.299	0.4770
-1.39519	-0.63560	-8.737	<.0001
-1.28815	-0.47914	-7.139	<.0001
-0.41124	0.47906	0.249	1.0000
-0.50354	0.40056	-0.372	1.0000
-0.68353	0.21855	-1.685	0.8757

-0.87685	0.05088	-2.910	0.1373
-1.49918	-0.71770	-9.271	<.0001
-1.39104	-0.56234	-7.703	<.0001
-0.52933	0.35853	-0.629	1.0000
-0.70986	0.17706	-1.963	0.7186
-0.90361	0.00983	-3.198	0.0619
-1.52291	-0.76179	-9.810	<.0001
-1.41596	-0.60523	-8.147	<.0001
-0.63049	0.26850	-1.316	0.9773
-0.82408	0.10110	-2.554	0.3065
-1.44559	-0.66831	-8.888	<.0001
-1.33849	-0.51190	-7.316	<.0001
-0.64123	0.28024	-1.280	0.9817
-1.26519	-0.48671	-7.354	<.0001
-1.15604	-0.33236	-5.905	<.0001
-1.09855	-0.29236	-5.638	<.0001
-0.98864	-0.13876	-4.335	0.0009
-0.18273	0.44624	1.369	0.9693

job\_category = Postdocs and Staff Researchers:

contrast	estimate	SE	df
mc Computing environments - mc Publicity	-0.03891	0.1410	Inf
mc Computing environments - mc Containerization	0.39238	0.1430	Inf
mc Computing environments - mc Documentation help	0.09297	0.1440	Inf
mc Computing environments - mc A learning community	0.19321	0.1410	Inf
mc Computing environments - mc Event planning	0.32620	0.1450	Inf
mc Computing environments - mc Mentoring programs	0.31718	0.1460	Inf
mc Computing environments - mc Education	0.18558	0.1440	Inf
mc Computing environments - mc Legal support	0.22683	0.1460	Inf
mc Computing environments - mc Industry partnerships	0.12057	0.1480	Inf
mc Computing environments - mc Sustainability grants	-0.45301	0.1230	Inf
mc Computing environments - mc Help finding funding	-0.31995	0.1300	Inf
mc Publicity - mc Containerization	0.43129	0.1390	Inf
mc Publicity - mc Documentation help	0.13188	0.1400	Inf
mc Publicity - mc A learning community	0.23212	0.1370	Inf
mc Publicity - mc Event planning	0.36511	0.1420	Inf
mc Publicity - mc Mentoring programs	0.35609	0.1430	Inf
mc Publicity - mc Education	0.22449	0.1410	Inf
mc Publicity - mc Legal support	0.26574	0.1420	Inf
mc Publicity - mc Industry partnerships	0.15948	0.1440	Inf
mc Publicity - mc Sustainability grants	-0.41410	0.1190	Inf
mc Publicity - mc Help finding funding	-0.28104	0.1260	Inf
mc Containerization - mc Documentation help	-0.29941	0.1420	Inf

mc Containerization - mc A learning community	-0.19917	0.1390	Inf
mc Containerization - mc Event planning	-0.06618	0.1430	Inf
mc Containerization - mc Mentoring programs	-0.07520	0.1440	Inf
mc Containerization - mc Education	-0.20680	0.1420	Inf
mc Containerization - mc Legal support	-0.16554	0.1440	Inf
mc Containerization - mc Industry partnerships	-0.27181	0.1460	Inf
mc Containerization - mc Sustainability grants	-0.84539	0.1220	Inf
mc Containerization - mc Help finding funding	-0.71233	0.1290	Inf
mc Documentation help - mc A learning community	0.10025	0.1410	Inf
mc Documentation help - mc Event planning	0.23323	0.1450	Inf
mc Documentation help - mc Mentoring programs	0.22422	0.1450	Inf
mc Documentation help - mc Education	0.09261	0.1440	Inf
mc Documentation help - mc Legal support	0.13387	0.1450	Inf
mc Documentation help - mc Industry partnerships	0.02760	0.1470	Inf
mc Documentation help - mc Sustainability grants	-0.54598	0.1230	Inf
mc Documentation help - mc Help finding funding	-0.41292	0.1300	Inf
mc A learning community - mc Event planning	0.13298	0.1420	Inf
mc A learning community - mc Mentoring programs	0.12397	0.1430	Inf
mc A learning community - mc Education	-0.00763	0.1410	Inf
mc A learning community - mc Legal support	0.03362	0.1420	Inf
mc A learning community - mc Industry partnerships	-0.07265	0.1440	Inf
mc A learning community - mc Sustainability grants	-0.64623	0.1200	Inf
mc A learning community - mc Help finding funding	-0.51317	0.1270	Inf
mc Event planning - mc Mentoring programs	-0.00902	0.1470	Inf
mc Event planning - mc Education	-0.14062	0.1450	Inf
mc Event planning - mc Legal support	-0.09936	0.1460	Inf
mc Event planning - mc Industry partnerships	-0.20563	0.1480	Inf
mc Event planning - mc Sustainability grants	-0.77921	0.1250	Inf
mc Event planning - mc Help finding funding	-0.64615	0.1310	Inf
mc Mentoring programs - mc Education	-0.13160	0.1460	Inf
mc Mentoring programs - mc Legal support	-0.09035	0.1480	Inf
mc Mentoring programs - mc Industry partnerships	-0.19661	0.1490	Inf
mc Mentoring programs - mc Sustainability grants	-0.77019	0.1270	Inf
mc Mentoring programs - mc Help finding funding	-0.63714	0.1330	Inf
mc Education - mc Legal support	0.04125	0.1460	Inf
mc Education - mc Industry partnerships	-0.06501	0.1480	Inf
mc Education - mc Sustainability grants	-0.63859	0.1240	Inf
mc Education - mc Help finding funding	-0.50553	0.1310	Inf
mc Legal support - mc Industry partnerships	-0.10627	0.1490	Inf
mc Legal support - mc Sustainability grants	-0.67985	0.1260	Inf
mc Legal support - mc Help finding funding	-0.54679	0.1320	Inf
mc Industry partnerships - mc Sustainability grants	-0.57358	0.1280	Inf
mc Industry partnerships - mc Help finding funding	-0.44052	0.1340	Inf

mc	Sustainability grants - mc	Help finding funding		0.13306	0.0996	Inf
asymp.LCL	asymp.UCL	z.ratio	p.value			
-0.49862	0.42080	-0.277	1.0000			
-0.07335	0.85811	2.753	0.2004			
-0.37722	0.56316	0.646	1.0000			
-0.26743	0.65385	1.371	0.9691			
-0.14816	0.80056	2.247	0.5149			
-0.16027	0.79463	2.171	0.5709			
-0.28606	0.65722	1.286	0.9810			
-0.25028	0.70394	1.554	0.9253			
-0.36191	0.60305	0.817	0.9997			
-0.85504	-0.05098	-3.682	0.0124			
-0.74384	0.10393	-2.467	0.3611			
-0.02306	0.88564	3.102	0.0817			
-0.32634	0.59010	0.941	0.9987			
-0.21662	0.68086	1.690	0.8730			
-0.09754	0.82776	2.579	0.2915			
-0.10968	0.82187	2.498	0.3407			
-0.23507	0.68405	1.596	0.9109			
-0.19929	0.73078	1.868	0.7796			
-0.31116	0.63012	1.107	0.9944			
-0.80181	-0.02639	-3.490	0.0243			
-0.69134	0.12926	-2.238	0.5213			
-0.76383	0.16500	-2.107	0.6178			
-0.65311	0.25478	-1.434	0.9570			
-0.53314	0.40078	-0.463	1.0000			
-0.54660	0.39621	-0.521	1.0000			
-0.67182	0.25823	-1.453	0.9527			
-0.63629	0.30520	-1.149	0.9924			
-0.74854	0.20492	-1.863	0.7821			
-1.24474	-0.44604	-6.918	<.0001			
-1.13265	-0.29201	-5.538	<.0001			
-0.35902	0.55952	0.713	0.9999			
-0.23905	0.70551	1.614	0.9045			
-0.25126	0.69969	1.541	0.9292			
-0.37753	0.56275	0.644	1.0000			
-0.34160	0.60933	0.920	0.9989			
-0.45309	0.50829	0.188	1.0000			
-0.94934	-0.14261	-4.423	0.0006			
-0.83713	0.01129	-3.181	0.0650			
-0.32949	0.59546	0.940	0.9987			
-0.34173	0.58967	0.870	0.9994			
-0.46756	0.45229	-0.054	1.0000			

-0.43192	0.49916	0.236	1.0000
-0.54438	0.39909	-0.503	1.0000
-1.03982	-0.25263	-5.366	<.0001
-0.92776	-0.09857	-4.045	0.0031
-0.48789	0.46986	-0.062	1.0000
-0.61387	0.33263	-0.971	0.9983
-0.57802	0.37930	-0.678	0.9999
-0.69057	0.27931	-1.386	0.9665
-1.18850	-0.36992	-6.222	<.0001
-1.07587	-0.21644	-4.914	0.0001
-0.60816	0.34496	-0.902	0.9991
-0.57291	0.39221	-0.612	1.0000
-0.68440	0.29117	-1.317	0.9771
-1.18362	-0.35677	-6.088	<.0001
-1.07017	-0.20410	-4.808	0.0001
-0.43563	0.51814	0.283	1.0000
-0.54806	0.41803	-0.440	1.0000
-1.04495	-0.23224	-5.136	<.0001
-0.93239	-0.07867	-3.870	0.0061
-0.59279	0.38026	-0.714	0.9999
-1.09192	-0.26777	-5.392	<.0001
-0.97917	-0.11441	-4.133	0.0021
-0.99062	-0.15654	-4.495	0.0004
-0.87721	-0.00384	-3.297	0.0457
-0.19235	0.45846	1.336	0.9745

```

job_category = Students:
contrast                                         estimate    SE  df
mc Computing environments - mc Publicity          0.27963 0.1470 Inf
mc Computing environments - mc Containerization  0.45699 0.1610 Inf
mc Computing environments - mc Documentation help 0.40891 0.1510 Inf
mc Computing environments - mc A learning community 0.44565 0.1520 Inf
mc Computing environments - mc Event planning      0.57943 0.1630 Inf
mc Computing environments - mc Mentoring programs  0.37691 0.1450 Inf
mc Computing environments - mc Education          0.38367 0.1490 Inf
mc Computing environments - mc Legal support       0.39743 0.1500 Inf
mc Computing environments - mc Industry partnerships 0.20652 0.1350 Inf
mc Computing environments - mc Sustainability grants -0.17255 0.0870 Inf
mc Computing environments - mc Help finding funding -0.04811 0.0997 Inf
mc Publicity - mc Containerization               0.17736 0.1810 Inf
mc Publicity - mc Documentation help              0.12928 0.1740 Inf
mc Publicity - mc A learning community            0.16602 0.1740 Inf
mc Publicity - mc Event planning                 0.29980 0.1830 Inf

```

mc Publicity - mc Mentoring programs	0.09728	0.1690	Inf
mc Publicity - mc Education	0.10404	0.1720	Inf
mc Publicity - mc Legal support	0.11780	0.1720	Inf
mc Publicity - mc Industry partnerships	-0.07311	0.1620	Inf
mc Publicity - mc Sustainability grants	-0.45218	0.1420	Inf
mc Publicity - mc Help finding funding	-0.32774	0.1440	Inf
mc Containerization - mc Documentation help	-0.04808	0.1840	Inf
mc Containerization - mc A learning community	-0.01134	0.1850	Inf
mc Containerization - mc Event planning	0.12244	0.1920	Inf
mc Containerization - mc Mentoring programs	-0.08008	0.1790	Inf
mc Containerization - mc Education	-0.07332	0.1820	Inf
mc Containerization - mc Legal support	-0.05956	0.1830	Inf
mc Containerization - mc Industry partnerships	-0.25047	0.1740	Inf
mc Containerization - mc Sustainability grants	-0.62954	0.1590	Inf
mc Containerization - mc Help finding funding	-0.50510	0.1590	Inf
mc Documentation help - mc A learning community	0.03674	0.1760	Inf
mc Documentation help - mc Event planning	0.17052	0.1850	Inf
mc Documentation help - mc Mentoring programs	-0.03200	0.1710	Inf
mc Documentation help - mc Education	-0.02524	0.1740	Inf
mc Documentation help - mc Legal support	-0.01148	0.1750	Inf
mc Documentation help - mc Industry partnerships	-0.20239	0.1660	Inf
mc Documentation help - mc Sustainability grants	-0.58146	0.1490	Inf
mc Documentation help - mc Help finding funding	-0.45702	0.1490	Inf
mc A learning community - mc Event planning	0.13378	0.1850	Inf
mc A learning community - mc Mentoring programs	-0.06874	0.1710	Inf
mc A learning community - mc Education	-0.06198	0.1740	Inf
mc A learning community - mc Legal support	-0.04822	0.1750	Inf
mc A learning community - mc Industry partnerships	-0.23913	0.1660	Inf
mc A learning community - mc Sustainability grants	-0.61820	0.1500	Inf
mc A learning community - mc Help finding funding	-0.49376	0.1500	Inf
mc Event planning - mc Mentoring programs	-0.20252	0.1800	Inf
mc Event planning - mc Education	-0.19576	0.1830	Inf
mc Event planning - mc Legal support	-0.18200	0.1840	Inf
mc Event planning - mc Industry partnerships	-0.37291	0.1760	Inf
mc Event planning - mc Sustainability grants	-0.75198	0.1620	Inf
mc Event planning - mc Help finding funding	-0.62754	0.1610	Inf
mc Mentoring programs - mc Education	0.00676	0.1690	Inf
mc Mentoring programs - mc Legal support	0.02052	0.1700	Inf
mc Mentoring programs - mc Industry partnerships	-0.17039	0.1600	Inf
mc Mentoring programs - mc Sustainability grants	-0.54946	0.1420	Inf
mc Mentoring programs - mc Help finding funding	-0.42502	0.1430	Inf
mc Education - mc Legal support	0.01376	0.1730	Inf
mc Education - mc Industry partnerships	-0.17715	0.1630	Inf

mc Education - mc Sustainability grants		-0.55622	0.1460	Inf
mc Education - mc Help finding funding		-0.43178	0.1460	Inf
mc Legal support - mc Industry partnerships		-0.19091	0.1640	Inf
mc Legal support - mc Sustainability grants		-0.56998	0.1470	Inf
mc Legal support - mc Help finding funding		-0.44554	0.1480	Inf
mc Industry partnerships - mc Sustainability grants		-0.37907	0.1280	Inf
mc Industry partnerships - mc Help finding funding		-0.25463	0.1320	Inf
mc Sustainability grants - mc Help finding funding		0.12444	0.0743	Inf
asymp.LCL	asymp.UCL	z.ratio	p.value	
-0.19968	0.75894	1.907	0.7554	
-0.07031	0.98429	2.832	0.1664	
-0.08603	0.90385	2.700	0.2260	
-0.05189	0.94319	2.927	0.1313	
0.04616	1.11270	3.551	0.0198	
-0.09751	0.85134	2.596	0.2815	
-0.10221	0.86955	2.581	0.2906	
-0.09311	0.88798	2.648	0.2530	
-0.23467	0.64771	1.530	0.9326	
-0.45673	0.11163	-1.984	0.7044	
-0.37408	0.27787	-0.482	1.0000	
-0.41538	0.77010	0.978	0.9981	
-0.43929	0.69785	0.743	0.9999	
-0.40379	0.73583	0.952	0.9985	
-0.29832	0.89792	1.638	0.8952	
-0.45414	0.64871	0.577	1.0000	
-0.45653	0.66461	0.607	1.0000	
-0.44375	0.67936	0.686	0.9999	
-0.60292	0.45670	-0.451	1.0000	
-0.91638	0.01202	-3.183	0.0646	
-0.79796	0.14249	-2.278	0.4926	
-0.65032	0.55416	-0.261	1.0000	
-0.61461	0.59193	-0.061	1.0000	
-0.50535	0.75023	0.637	1.0000	
-0.66621	0.50605	-0.446	1.0000	
-0.66930	0.52266	-0.402	1.0000	
-0.65709	0.53798	-0.326	1.0000	
-0.82050	0.31957	-1.436	0.9566	
-1.14918	-0.10990	-3.959	0.0043	
-1.02508	0.01489	-3.174	0.0663	
-0.54004	0.61352	0.208	1.0000	
-0.43435	0.77539	0.921	0.9989	
-0.59105	0.52705	-0.187	1.0000	
-0.59358	0.54311	-0.145	1.0000	

-0.58370	0.56075	-0.066	1.0000
-0.74429	0.33952	-1.221	0.9875
-1.06798	-0.09494	-3.906	0.0053
-0.94547	0.03144	-3.058	0.0926
-0.47172	0.73928	0.722	0.9999
-0.62883	0.49136	-0.401	1.0000
-0.63156	0.50761	-0.356	1.0000
-0.62149	0.52506	-0.275	1.0000
-0.78233	0.30407	-1.439	0.9560
-1.10859	-0.12781	-4.120	0.0022
-0.98500	-0.00251	-3.285	0.0475
-0.79210	0.38706	-1.123	0.9938
-0.79397	0.40246	-1.069	0.9959
-0.78444	0.42045	-0.987	0.9980
-0.94709	0.20127	-2.122	0.6065
-1.28013	-0.22383	-4.653	0.0002
-1.15528	-0.09980	-3.886	0.0058
-0.54504	0.55856	0.040	1.0000
-0.53514	0.57619	0.121	1.0000
-0.69447	0.35370	-1.062	0.9961
-1.01423	-0.08469	-3.864	0.0063
-0.89225	0.04221	-2.973	0.1165
-0.55126	0.57878	0.080	1.0000
-0.71099	0.35669	-1.084	0.9954
-1.03302	-0.07943	-3.812	0.0076
-0.91035	0.04679	-2.948	0.1242
-0.72809	0.34627	-1.161	0.9917
-1.05152	-0.08844	-3.868	0.0062
-0.92848	0.03739	-3.015	0.1041
-0.79837	0.04023	-2.954	0.1223
-0.68506	0.17580	-1.933	0.7383
-0.11849	0.36737	1.674	0.8802

job\_category = Non-research Staff:

contrast	estimate	SE	df
mc Computing environments - mc Publicity	0.50790	0.1160	Inf
mc Computing environments - mc Containerization	0.53326	0.1160	Inf
mc Computing environments - mc Documentation help	0.24149	0.1110	Inf
mc Computing environments - mc A learning community	0.04472	0.1090	Inf
mc Computing environments - mc Event planning	0.53094	0.1160	Inf
mc Computing environments - mc Mentoring programs	0.24534	0.1140	Inf
mc Computing environments - mc Education	0.19929	0.1130	Inf
mc Computing environments - mc Legal support	0.14308	0.1130	Inf

mc Computing environments - mc Industry partnerships	0.41088	0.1190	Inf
mc Computing environments - mc Sustainability grants	-0.17207	0.1120	Inf
mc Computing environments - mc Help finding funding	-0.01530	0.1150	Inf
mc Publicity - mc Containerization	0.02537	0.1180	Inf
mc Publicity - mc Documentation help	-0.26641	0.1140	Inf
mc Publicity - mc A learning community	-0.46318	0.1130	Inf
mc Publicity - mc Event planning	0.02305	0.1180	Inf
mc Publicity - mc Mentoring programs	-0.26256	0.1160	Inf
mc Publicity - mc Education	-0.30860	0.1160	Inf
mc Publicity - mc Legal support	-0.36482	0.1160	Inf
mc Publicity - mc Industry partnerships	-0.09702	0.1210	Inf
mc Publicity - mc Sustainability grants	-0.67997	0.1150	Inf
mc Publicity - mc Help finding funding	-0.52320	0.1180	Inf
mc Containerization - mc Documentation help	-0.29178	0.1150	Inf
mc Containerization - mc A learning community	-0.48855	0.1130	Inf
mc Containerization - mc Event planning	-0.00232	0.1190	Inf
mc Containerization - mc Mentoring programs	-0.28792	0.1170	Inf
mc Containerization - mc Education	-0.33397	0.1170	Inf
mc Containerization - mc Legal support	-0.39019	0.1160	Inf
mc Containerization - mc Industry partnerships	-0.12239	0.1210	Inf
mc Containerization - mc Sustainability grants	-0.70533	0.1150	Inf
mc Containerization - mc Help finding funding	-0.54857	0.1180	Inf
mc Documentation help - mc A learning community	-0.19677	0.1080	Inf
mc Documentation help - mc Event planning	0.28946	0.1140	Inf
mc Documentation help - mc Mentoring programs	0.00385	0.1120	Inf
mc Documentation help - mc Education	-0.04219	0.1120	Inf
mc Documentation help - mc Legal support	-0.09841	0.1110	Inf
mc Documentation help - mc Industry partnerships	0.16939	0.1170	Inf
mc Documentation help - mc Sustainability grants	-0.41356	0.1110	Inf
mc Documentation help - mc Help finding funding	-0.25679	0.1140	Inf
mc A learning community - mc Event planning	0.48623	0.1130	Inf
mc A learning community - mc Mentoring programs	0.20062	0.1100	Inf
mc A learning community - mc Education	0.15458	0.1100	Inf
mc A learning community - mc Legal support	0.09836	0.1090	Inf
mc A learning community - mc Industry partnerships	0.36616	0.1160	Inf
mc A learning community - mc Sustainability grants	-0.21679	0.1080	Inf
mc A learning community - mc Help finding funding	-0.06002	0.1120	Inf
mc Event planning - mc Mentoring programs	-0.28560	0.1170	Inf
mc Event planning - mc Education	-0.33165	0.1160	Inf
mc Event planning - mc Legal support	-0.38787	0.1160	Inf
mc Event planning - mc Industry partnerships	-0.12007	0.1210	Inf
mc Event planning - mc Sustainability grants	-0.70301	0.1150	Inf
mc Event planning - mc Help finding funding	-0.54625	0.1180	Inf

mc	Mentoring programs	-	mc	Education		-0.04605	0.1140	Inf
mc	Mentoring programs	-	mc	Legal support		-0.10226	0.1140	Inf
mc	Mentoring programs	-	mc	Industry partnerships		0.16554	0.1190	Inf
mc	Mentoring programs	-	mc	Sustainability grants		-0.41741	0.1130	Inf
mc	Mentoring programs	-	mc	Help finding funding		-0.26064	0.1160	Inf
mc	Education	-	mc	Legal support		-0.05622	0.1130	Inf
mc	Education	-	mc	Industry partnerships		0.21158	0.1190	Inf
mc	Education	-	mc	Sustainability grants		-0.37136	0.1130	Inf
mc	Education	-	mc	Help finding funding		-0.21460	0.1160	Inf
mc	Legal support	-	mc	Industry partnerships		0.26780	0.1190	Inf
mc	Legal support	-	mc	Sustainability grants		-0.31515	0.1110	Inf
mc	Legal support	-	mc	Help finding funding		-0.15838	0.1150	Inf
mc	Industry partnerships	-	mc	Sustainability grants		-0.58295	0.1180	Inf
mc	Industry partnerships	-	mc	Help finding funding		-0.42618	0.1210	Inf
mc	Sustainability grants	-	mc	Help finding funding		0.15677	0.1130	Inf
asymp.LCL								
asymp.UCL								
z.ratio								
p.value								
0.12940	0.88640		4.385	0.0007				
0.15404	0.91249		4.595	0.0003				
-0.12274	0.60572		2.167	0.5741				
-0.31251	0.40195		0.409	1.0000				
0.15130	0.91059		4.570	0.0003				
-0.12603	0.61671		2.159	0.5798				
-0.17107	0.56966		1.759	0.8404				
-0.22517	0.51132		1.270	0.9828				
0.02304	0.79871		3.462	0.0268				
-0.53764	0.19350		-1.538	0.9301				
-0.39174	0.36113		-0.133	1.0000				
-0.36150	0.41223		0.214	1.0000				
-0.63998	0.10716		-2.331	0.4545				
-0.83184	-0.09451		-4.106	0.0024				
-0.36370	0.40979		0.195	1.0000				
-0.64299	0.11788		-2.255	0.5089				
-0.68870	0.07149		-2.653	0.2500				
-0.74243	0.01279		-3.157	0.0697				
-0.49181	0.29777		-0.803	0.9997				
-1.05513	-0.30480		-5.923	<.0001				
-0.90843	-0.13797		-4.438	0.0006				
-0.66655	0.08300		-2.544	0.3122				
-0.85772	-0.11937		-4.325	0.0009				
-0.39019	0.38555		-0.020	1.0000				
-0.66977	0.09393		-2.464	0.3628				
-0.71474	0.04680		-2.866	0.1531				
-0.76880	-0.01158		-3.368	0.0365				

-0.51923	0.27445	-1.008	0.9976
-1.08241	-0.32825	-6.113	<.0001
-0.93571	-0.16142	-4.631	0.0002
-0.55004	0.15650	-1.820	0.8072
-0.08470	0.66361	2.528	0.3221
-0.36328	0.37099	0.034	1.0000
-0.40785	0.32346	-0.377	1.0000
-0.46157	0.26475	-0.886	0.9993
-0.21414	0.55292	1.443	0.9549
-0.77496	-0.05215	-3.740	0.0100
-0.62891	0.11533	-2.255	0.5091
0.11765	0.85480	4.311	0.0010
-0.16031	0.56156	1.816	0.8093
-0.20497	0.51412	1.405	0.9629
-0.25785	0.45457	0.902	0.9991
-0.01200	0.74432	3.164	0.0683
-0.57092	0.13734	-2.001	0.6933
-0.42594	0.30590	-0.536	1.0000
-0.66647	0.09526	-2.451	0.3717
-0.71207	0.04877	-2.849	0.1597
-0.76541	-0.01032	-3.357	0.0378
-0.51582	0.27569	-0.991	0.9979
-1.07868	-0.32734	-6.116	<.0001
-0.93233	-0.16017	-4.624	0.0002
-0.41932	0.32722	-0.403	1.0000
-0.47335	0.26882	-0.901	0.9991
-0.22360	0.55467	1.390	0.9657
-0.78640	-0.04842	-3.697	0.0118
-0.63983	0.11854	-2.246	0.5155
-0.42548	0.31304	-0.498	1.0000
-0.17754	0.60070	1.777	0.8308
-0.73912	-0.00360	-3.300	0.0453
-0.59298	0.16379	-1.853	0.7880
-0.11953	0.65513	2.260	0.5059
-0.67901	0.04871	-2.830	0.1671
-0.53332	0.21656	-1.380	0.9674
-0.96766	-0.19824	-4.952	<.0001
-0.82027	-0.03209	-3.534	0.0210
-0.21344	0.52698	1.384	0.9668

Confidence level used: 0.95

Conf-level adjustment: tukey method for comparing a family of 12 estimates

P value adjustment: tukey method for comparing a family of 12 estimates

Save results for supplement.

```
# From utils.R
write_df_to_file(by_job, "supplementary_tables/solutions_pairwise_contrasts_byjob.tsv")
```

And do the same, but sorting by solution.

```
by_soln <- summary(
  pairs(emm.eq.job.res, by = "solution"),
  infer = TRUE # infer CIs
)
by_soln

solution = Computing environments:
contrast                               estimate      SE
mc Faculty - mc Postdocs and Staff Researchers    0.0162 0.1690
mc Faculty - mc Students                  -0.4426 0.1460
mc Faculty - (mc Non-research Staff)        0.0287 0.1510
mc Postdocs and Staff Researchers - mc Students   -0.4588 0.1510
mc Postdocs and Staff Researchers - (mc Non-research Staff)  0.0125 0.1560
mc Students - (mc Non-research Staff)          0.4713 0.1300
df asympt.LCL asympt.UCL z.ratio p.value
Inf  -0.41851   0.45096   0.096  0.9997
Inf  -0.81759  -0.06761  -3.032  0.0130
Inf  -0.36044   0.41779   0.189  0.9976
Inf  -0.84563  -0.07202  -3.047  0.0124
Inf  -0.38818   0.41309   0.080  0.9998
Inf   0.13648   0.80608   3.616  0.0017

solution = Publicity:
contrast                               estimate      SE
mc Faculty - mc Postdocs and Staff Researchers   -0.2589 0.1720
mc Faculty - mc Students                      -0.3992 0.1910
mc Faculty - (mc Non-research Staff)           0.3004 0.1610
mc Postdocs and Staff Researchers - mc Students  -0.1403 0.1860
mc Postdocs and Staff Researchers - (mc Non-research Staff)  0.5593 0.1550
mc Students - (mc Non-research Staff)           0.6995 0.1760
df asympt.LCL asympt.UCL z.ratio p.value
Inf  -0.70076   0.18295  -1.505  0.4342
Inf  -0.89016   0.09179  -2.089  0.1567
Inf  -0.11266   0.71338   1.868  0.2418
Inf  -0.61876   0.33820  -0.753  0.8753
```

```

Inf  0.16068  0.95785  3.605  0.0018
Inf  0.24709  1.15199  3.972  0.0004

```

solution = Containerization:

	contrast	estimate	SE
mc Faculty - mc Postdocs and Staff Researchers	0.0295	0.1750	
mc Faculty - mc Students	-0.3647	0.2040	
mc Faculty - (mc Non-research Staff)	0.1828	0.1610	
mc Postdocs and Staff Researchers - mc Students	-0.3942	0.2020	
mc Postdocs and Staff Researchers - (mc Non-research Staff)	0.1533	0.1590	
mc Students - (mc Non-research Staff)	0.5475	0.1910	
df asympt.LCL asympt.UCL z.ratio p.value			
Inf -0.41974 0.47867 0.169 0.9983			
Inf -0.88919 0.15970 -1.787 0.2797			
Inf -0.23012 0.59573 1.137 0.6664			
Inf -0.91444 0.12601 -1.947 0.2086			
Inf -0.25449 0.56116 0.966 0.7688			
Inf  0.05807 1.03703 2.874 0.0211			

solution = Documentation help:

	contrast	estimate	SE
mc Faculty - mc Postdocs and Staff Researchers	-0.3236	0.1740	
mc Faculty - mc Students	-0.4665	0.1950	
mc Faculty - (mc Non-research Staff)	-0.1626	0.1560	
mc Postdocs and Staff Researchers - mc Students	-0.1429	0.1950	
mc Postdocs and Staff Researchers - (mc Non-research Staff)	0.1610	0.1570	
mc Students - (mc Non-research Staff)	0.3039	0.1790	
df asympt.LCL asympt.UCL z.ratio p.value			
Inf -0.77003 0.12281 -1.862 0.2444			
Inf -0.96672 0.03374 -2.396 0.0779			
Inf -0.56278 0.23751 -1.044 0.7234			
Inf -0.64440 0.35864 -0.732 0.8843			
Inf -0.24117 0.56312 1.028 0.7328			
Inf -0.15728 0.76499 1.693 0.3274			

solution = A learning community:

	contrast	estimate	SE
mc Faculty - mc Postdocs and Staff Researchers	-0.3525	0.1670	
mc Faculty - mc Students	-0.5588	0.1920	
mc Faculty - (mc Non-research Staff)	-0.4885	0.1490	
mc Postdocs and Staff Researchers - mc Students	-0.2064	0.1940	
mc Postdocs and Staff Researchers - (mc Non-research Staff)	-0.1360	0.1520	
mc Students - (mc Non-research Staff)	0.0703	0.1790	

```

df asymp.LCL asymp.UCL z.ratio p.value
Inf -0.78266  0.07774 -2.105  0.1515
Inf -1.05171 -0.06597 -2.913  0.0188
Inf -0.87073 -0.10627 -3.283  0.0057
Inf -0.70593  0.29316 -1.061  0.7131
Inf -0.52711  0.25503 -0.894  0.8081
Inf -0.38870  0.52939  0.394  0.9793

solution = Event planning:
contrast                                         estimate      SE
mc Faculty - mc Postdocs and Staff Researchers -0.3125 0.1730
mc Faculty - mc Students                      -0.5181 0.2030
mc Faculty - (mc Non-research Staff)          -0.0953 0.1560
mc Postdocs and Staff Researchers - mc Students -0.2056 0.2070
mc Postdocs and Staff Researchers - (mc Non-research Staff) 0.2172 0.1610
mc Students - (mc Non-research Staff)          0.4228 0.1930

df asymp.LCL asymp.UCL z.ratio p.value
Inf -0.75643  0.13140 -1.809  0.2692
Inf -1.03880  0.00258 -2.556  0.0517
Inf -0.49591  0.30527 -0.611  0.9285
Inf -0.73614  0.32496 -0.996  0.7520
Inf -0.19658  0.63098  1.349  0.5319
Inf -0.07243  0.91801  2.193  0.1250

solution = Mentoring programs:
contrast                                         estimate      SE
mc Faculty - mc Postdocs and Staff Researchers -0.3554 0.1710
mc Faculty - mc Students                      -0.7545 0.1850
mc Faculty - (mc Non-research Staff)          -0.4148 0.1520
mc Postdocs and Staff Researchers - mc Students -0.3991 0.1920
mc Postdocs and Staff Researchers - (mc Non-research Staff) -0.0594 0.1610
mc Students - (mc Non-research Staff)          0.3397 0.1750

df asymp.LCL asymp.UCL z.ratio p.value
Inf -0.79593  0.08505 -2.073  0.1620
Inf -1.23068 -0.27839 -4.071  0.0003
Inf -0.80575 -0.02391 -2.726  0.0325
Inf -0.89328  0.09510 -2.075  0.1614
Inf -0.47255  0.35378 -0.369  0.9828
Inf -0.11114  0.79055  1.936  0.2131

solution = Education:
contrast                                         estimate      SE
mc Faculty - mc Postdocs and Staff Researchers -0.4016 0.1720

```

mc Faculty - mc Students	-0.6624	0.1900
mc Faculty - (mc Non-research Staff)	-0.3755	0.1540
mc Postdocs and Staff Researchers - mc Students	-0.2607	0.1940
mc Postdocs and Staff Researchers - (mc Non-research Staff)	0.0262	0.1590
mc Students - (mc Non-research Staff)	0.2869	0.1780
df asymp.LCL asymp.UCL z.ratio p.value		
Inf -0.84346 0.04017 -2.335 0.0901		
Inf -1.15080 -0.17394 -3.484 0.0028		
Inf -0.77172 0.02077 -2.434 0.0707		
Inf -0.75821 0.23676 -1.346 0.5332		
Inf -0.38171 0.43405 0.165 0.9984		
Inf -0.17097 0.74476 1.610 0.3730		
solution = Legal support:		
contrast	estimate	SE
mc Faculty - mc Postdocs and Staff Researchers	-0.1794	0.1740
mc Faculty - mc Students	-0.4676	0.1920
mc Faculty - (mc Non-research Staff)	-0.2507	0.1540
mc Postdocs and Staff Researchers - mc Students	-0.2882	0.1960
mc Postdocs and Staff Researchers - (mc Non-research Staff)	-0.0713	0.1590
mc Students - (mc Non-research Staff)	0.2169	0.1790
df asymp.LCL asymp.UCL z.ratio p.value		
Inf -0.62577 0.26699 -1.032 0.7304		
Inf -0.96010 0.02487 -2.439 0.0699		
Inf -0.64634 0.14495 -1.628 0.3628		
Inf -0.79171 0.21527 -1.471 0.4553		
Inf -0.48084 0.33823 -0.447 0.9702		
Inf -0.24234 0.67618 1.213 0.6183		
solution = Industry partnerships:		
contrast	estimate	SE
mc Faculty - mc Postdocs and Staff Researchers	-0.1052	0.1780
mc Faculty - mc Students	-0.4780	0.1800
mc Faculty - (mc Non-research Staff)	0.1976	0.1620
mc Postdocs and Staff Researchers - mc Students	-0.3729	0.1830
mc Postdocs and Staff Researchers - (mc Non-research Staff)	0.3028	0.1650
mc Students - (mc Non-research Staff)	0.6756	0.1670
df asymp.LCL asymp.UCL z.ratio p.value		
Inf -0.56223 0.35190 -0.591 0.9348		
Inf -0.93997 -0.01610 -2.659 0.0392		
Inf -0.21882 0.61402 1.219 0.6147		
Inf -0.84196 0.09623 -2.042 0.1726		
Inf -0.12182 0.72734 1.832 0.2582		

```

Inf    0.24575   1.10551   4.038  0.0003

solution = Sustainability grants:
contrast                                         estimate      SE
mc Faculty - mc Postdocs and Staff Researchers      0.0167 0.0952
mc Faculty - mc Students                          -0.1616 0.0694
mc Faculty - (mc Non-research Staff)              0.3101 0.1130
mc Postdocs and Staff Researchers - mc Students     -0.1784 0.0742
mc Postdocs and Staff Researchers - (mc Non-research Staff) 0.2934 0.1160
mc Students - (mc Non-research Staff)               0.4718 0.0955
df asymp.LCL asymp.UCL z.ratio p.value
Inf  -0.22773   0.26116   0.176  0.9981
Inf  -0.33987   0.01658   -2.330  0.0913
Inf   0.02077   0.59945   2.753  0.0301
Inf  -0.36891   0.01219   -2.405  0.0762
Inf  -0.00368   0.59047   2.537  0.0544
Inf   0.22634   0.71718   4.938  <.0001

solution = Help finding funding:
contrast                                         estimate      SE
mc Faculty - mc Postdocs and Staff Researchers      0.0180 0.1290
mc Faculty - mc Students                          -0.1690 0.1160
mc Faculty - (mc Non-research Staff)              0.3351 0.1340
mc Postdocs and Staff Researchers - mc Students     -0.1870 0.1190
mc Postdocs and Staff Researchers - (mc Non-research Staff) 0.3171 0.1360
mc Students - (mc Non-research Staff)               0.5041 0.1240
df asymp.LCL asymp.UCL z.ratio p.value
Inf  -0.31338   0.34942   0.140  0.9990
Inf  -0.46788   0.12996   -1.452  0.4668
Inf  -0.00848   0.67872   2.506  0.0590
Inf  -0.49198   0.11802   -1.575  0.3930
Inf  -0.03186   0.66607   2.334  0.0903
Inf   0.18581   0.82235   4.069  0.0003

```

Confidence level used: 0.95

Conf-level adjustment: tukey method for comparing a family of 4 estimates

P value adjustment: tukey method for comparing a family of 4 estimates

Save results for supplement.

```
# From utils.R
write_df_to_file(by_soln, "supplementary_tables/solutions_pairwise_contrasts_bysoln.tsv")
```

Let's glance at the significant differences.

```
# Because there are so many significant comparisons,  
# let's be stringent  
sig_by_job <- subset(by_job, p.value < 0.0005)  
sig_by_job
```

```
contrast  
5      mc Computing environments - mc Event planning  
6      mc Computing environments - mc Mentoring programs  
20     mc Publicity - mc Sustainability grants  
29     mc Containerization - mc Sustainability grants  
30     mc Containerization - mc Help finding funding  
37     mc Documentation help - mc Sustainability grants  
38     mc Documentation help - mc Help finding funding  
44     mc A learning community - mc Sustainability grants  
45     mc A learning community - mc Help finding funding  
50     mc Event planning - mc Sustainability grants  
51     mc Event planning - mc Help finding funding  
55     mc Mentoring programs - mc Sustainability grants  
56     mc Mentoring programs - mc Help finding funding  
59     mc Education - mc Sustainability grants  
60     mc Education - mc Help finding funding  
62     mc Legal support - mc Sustainability grants  
63     mc Legal support - mc Help finding funding  
64     mc Industry partnerships - mc Sustainability grants  
95     mc Containerization - mc Sustainability grants  
96     mc Containerization - mc Help finding funding  
110    mc A learning community - mc Sustainability grants  
116    mc Event planning - mc Sustainability grants  
117    mc Event planning - mc Help finding funding  
121    mc Mentoring programs - mc Sustainability grants  
122    mc Mentoring programs - mc Help finding funding  
125    mc Education - mc Sustainability grants  
128    mc Legal support - mc Sustainability grants  
130    mc Industry partnerships - mc Sustainability grants  
182    mc Event planning - mc Sustainability grants  
200    mc Computing environments - mc Containerization  
203    mc Computing environments - mc Event planning  
218    mc Publicity - mc Sustainability grants  
227    mc Containerization - mc Sustainability grants  
228    mc Containerization - mc Help finding funding
```

248	mc Event planning - mc Sustainability grants
249	mc Event planning - mc Help finding funding
262	mc Industry partnerships - mc Sustainability grants
	job_category estimate SE df asymp.LCL
5	Faculty 0.6549404 0.1383278 Inf 0.2028847
6	Faculty 0.6888481 0.1359182 Inf 0.2446670
20	Faculty -0.6897175 0.1246919 Inf -1.0972112
29	Faculty -0.8326377 0.1244847 Inf -1.2394542
30	Faculty -0.7008841 0.1312171 Inf -1.1297021
37	Faculty -0.8863025 0.1220734 Inf -1.2852387
38	Faculty -0.7545489 0.1289687 Inf -1.1760190
44	Faculty -1.0153942 0.1162150 Inf -1.3951852
45	Faculty -0.8836407 0.1237773 Inf -1.2881454
50	Faculty -1.1084421 0.1195653 Inf -1.4991821
51	Faculty -0.9766886 0.1267895 Inf -1.3910373
55	Faculty -1.1423498 0.1164505 Inf -1.5229105
56	Faculty -1.0105963 0.1240400 Inf -1.4159595
59	Faculty -1.0569497 0.1189241 Inf -1.4455941
60	Faculty -0.9251962 0.1264674 Inf -1.3384922
62	Faculty -0.8759528 0.1191070 Inf -1.2651948
63	Faculty -0.7441992 0.1260213 Inf -1.1560374
64	Faculty -0.6954577 0.1233462 Inf -1.0985536
95	Postdocs and Staff Researchers -0.8453910 0.1222004 Inf -1.2447424
96	Postdocs and Staff Researchers -0.7123321 0.1286174 Inf -1.1326544
110	Postdocs and Staff Researchers -0.6462254 0.1204395 Inf -1.0398220
116	Postdocs and Staff Researchers -0.7792098 0.1252404 Inf -1.1884959
117	Postdocs and Staff Researchers -0.6461509 0.1314915 Inf -1.0758656
121	Postdocs and Staff Researchers -0.7701944 0.1265056 Inf -1.1836151
122	Postdocs and Staff Researchers -0.6371354 0.1325076 Inf -1.0701709
125	Postdocs and Staff Researchers -0.6385922 0.1243440 Inf -1.0449489
128	Postdocs and Staff Researchers -0.6798460 0.1260943 Inf -1.0919226
130	Postdocs and Staff Researchers -0.5735799 0.1276135 Inf -0.9906213
182	Students -0.7519809 0.1616113 Inf -1.2801274
200	Non-research Staff 0.5332636 0.1160426 Inf 0.1540358
203	Non-research Staff 0.5309440 0.1161705 Inf 0.1512982
218	Non-research Staff -0.6799672 0.1147994 Inf -1.0551319
227	Non-research Staff -0.7053335 0.1153851 Inf -1.0824125
228	Non-research Staff -0.5485665 0.1184652 Inf -0.9357112
248	Non-research Staff -0.7030140 0.1149538 Inf -1.0786835
249	Non-research Staff -0.5462469 0.1181389 Inf -0.9323254
262	Non-research Staff -0.5829469 0.1177207 Inf -0.9676586
	asymp.UCL z.ratio p.value
5	1.1069962 4.734699 1.388367e-04

6	1.1330292	5.068109	2.590106e-05
20	-0.2822239	-5.531373	2.076395e-06
29	-0.4258211	-6.688674	1.485164e-09
30	-0.2720661	-5.341408	6.000927e-06
37	-0.4873662	-7.260408	2.554301e-11
38	-0.3330789	-5.850638	3.215137e-07
44	-0.6356033	-8.737207	9.514611e-14
45	-0.4791360	-7.138956	6.212852e-11
50	-0.7177022	-9.270598	1.266764e-13
51	-0.5623399	-7.703227	9.453549e-13
55	-0.7617891	-9.809746	1.245670e-13
56	-0.6052330	-8.147340	1.683098e-13
59	-0.6683053	-8.887600	8.648637e-14
60	-0.5119001	-7.315688	1.697409e-11
62	-0.4867107	-7.354337	1.273992e-11
63	-0.3323611	-5.905344	2.311823e-07
64	-0.2923618	-5.638257	1.124693e-06
95	-0.4460396	-6.918070	3.021001e-10
96	-0.2920098	-5.538379	1.995309e-06
110	-0.2526288	-5.365562	5.254050e-06
116	-0.3699237	-6.221714	3.237886e-08
117	-0.2164362	-4.914013	5.710042e-05
121	-0.3567737	-6.088225	7.511344e-08
122	-0.2041000	-4.808292	9.681196e-05
125	-0.2322355	-5.135689	1.817081e-05
128	-0.2677695	-5.391570	4.550438e-06
130	-0.1565385	-4.494665	4.321159e-04
182	-0.2238344	-4.653021	2.057479e-04
200	0.9124913	4.595411	2.703628e-04
203	0.9105898	4.570384	3.040797e-04
218	-0.3048024	-5.923092	2.075892e-07
227	-0.3282546	-6.112865	6.439254e-08
228	-0.1614218	-4.630613	2.289050e-04
248	-0.3273444	-6.115621	6.329075e-08
249	-0.1601684	-4.623767	2.364616e-04
262	-0.1982351	-4.951948	4.711072e-05

```
sig_by_soln <- subset(by_soln, p.value < 0.05)
sig_by_soln
```

```
2                                     contrast
                                     mc Faculty - mc Students
```

		mc Postdocs and Staff Researchers - mc Students						
		mc Students - (mc Non-research Staff)						
4								
6								
11	mc Postdocs and Staff Researchers	- (mc Non-research Staff)						
12								
18								
26								
27								
38								
39								
44								
56								
60								
63								
66								
72								
		solution	estimate	SE	df	asymp.LCL	asymp.UCL	
2	Computing environments	-0.4425989	0.1459660	Inf	-0.81759018	-0.06760760		
4	Computing environments	-0.4588231	0.1505653	Inf	-0.84563008	-0.07201615		
6	Computing environments	0.4712768	0.1303217	Inf	0.13647631	0.80607726		
11	Publicity	0.5592622	0.1551499	Inf	0.16067722	0.95784717		
12	Publicity	0.6995423	0.1761166	Inf	0.24709308	1.15199158		
18	Containerization	0.5475497	0.1905313	Inf	0.05806868	1.03703070		
26	A learning community	-0.5588410	0.1918513	Inf	-1.05171317	-0.06596874		
27	A learning community	-0.4884963	0.1487836	Inf	-0.87072610	-0.10626660		
38	Mentoring programs	-0.7545348	0.1853409	Inf	-1.23068154	-0.27838811		
39	Mentoring programs	-0.4148289	0.1521663	Inf	-0.80574893	-0.02390883		
44	Education	-0.6623738	0.1901221	Inf	-1.15080345	-0.17394418		
56	Industry partnerships	-0.4780319	0.1798083	Inf	-0.93996518	-0.01609858		
60	Industry partnerships	0.6756306	0.1673319	Inf	0.24574967	1.10551161		
63	Sustainability grants	0.3101096	0.1126268	Inf	0.02076775	0.59945146		
66	Sustainability grants	0.4717569	0.0955300	Inf	0.22633727	0.71717647		
72	Help finding funding	0.5040808	0.1238873	Inf	0.18581024	0.82235131		
		z.ratio	p.value					
2	-3.032205	1.297267e-02						
4	-3.047337	1.236403e-02						
6	3.616258	1.700432e-03						
11	3.604658	1.776658e-03						
12	3.972040	4.142473e-04						
18	2.873804	2.113462e-02						
26	-2.912885	1.878472e-02						
27	-3.283268	5.661492e-03						
38	-4.071064	2.732612e-04						
39	-2.726155	3.249277e-02						

```

44 -3.483940 2.780828e-03
56 -2.658564 3.924501e-02
60  4.037668 3.147720e-04
63  2.753426 3.006602e-02
66  4.938311 4.698058e-06
72  4.068864 2.758288e-04

```

Okay, so here, the “estimate” column shows the difference in estimated marginal means for the two levels of interest, holding the other factor level constant (of my two factors, job and solution). So when the contrast is Computing environments vs. A learning community, the job\_category is Faculty, and the estimate is 0.57, this indicates that the difference between the estimates of faculty’s average rating of computer environments and their average rating of a learning community is 0.56, on a three-point scale.

```

subset(
  summary(all_means),
  job_category == "Faculty" & solution == "Computing environments"
)$mean.class -
subset(
  summary(all_means),
  job_category == "Faculty" & solution == "A learning community"
)$mean.class

```

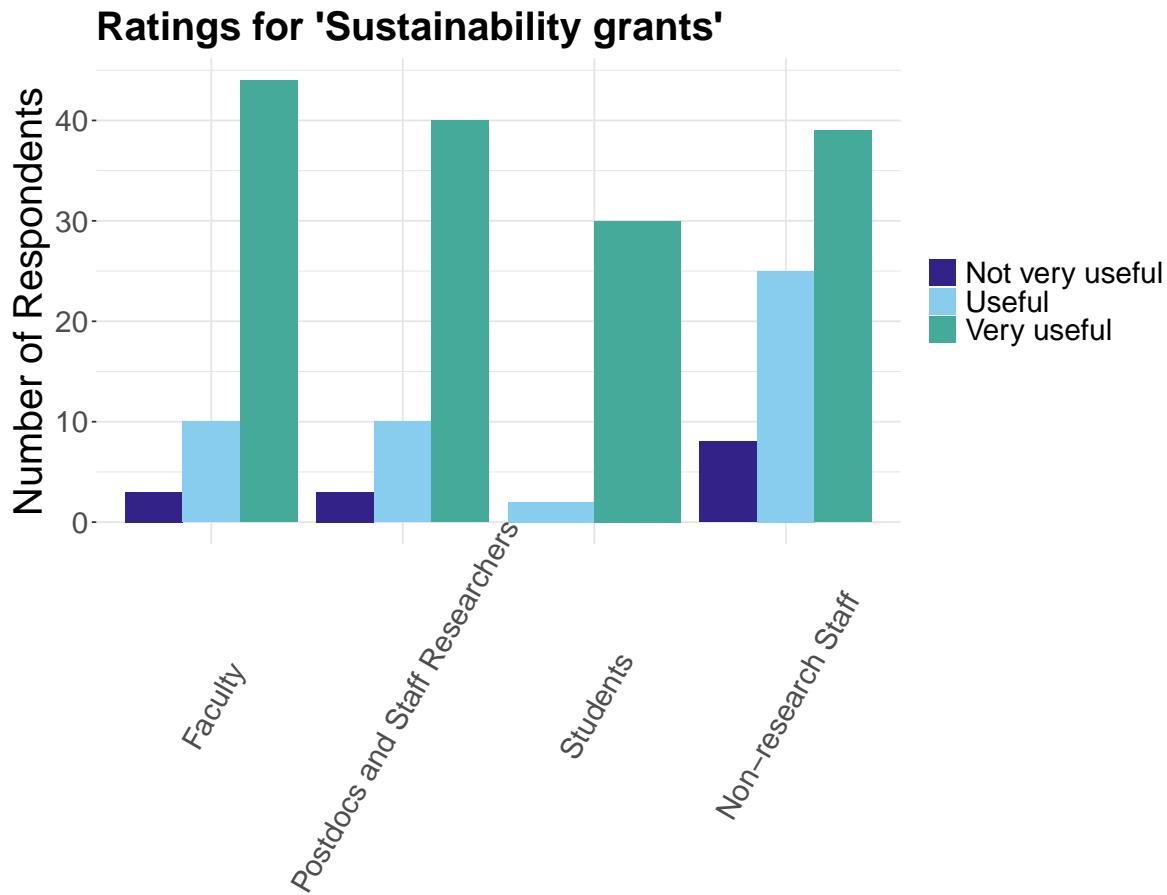
```
[1] 0.5618926
```

Sustainability grants and Finding funding show up frequently as being significantly higher than some of the other solutions. Let’s plot the distributions of responses for sustainability grants, as a sanity check.

```

grant_ratings <- grouped_bar_chart(
  df = subset(combined, solution=="Sustainability grants"),
  x_var = "job_category",
  fill_var = "utility",
  title = "Ratings for 'Sustainability grants'")
grant_ratings

```



```
save_plot("solns_grants.tiff", 12, 10, p=grant_ratings)
```

### Kruskal-Wallis test for ranking differences between groups

Non-parametric corroboration of the extent of disagreement between groups. Whereas above, we tested for differences in mean ratings, here we are testing for differences in the distributions of ratings for each solution.

```
combined2 <- combined %>%
  mutate(
    utility_score = recode(
      utility,
      "Non-applicable" = 0L,
```

```

"Not very useful" = 0L,
"Useful" = 1L,
"Very useful" = 2L
)
)

kw_results <- sapply(split(combined2, combined2$solution), function(df) {
  kruskal.test(utility_score ~ job_category, data = df)$p.value
})

p_adj_kw <- p.adjust(kw_results, "holm")

p_adj_kw < 0.05

```

Computing environments		Publicity	Containerization
	FALSE	TRUE	FALSE
Documentation help	A learning community		Event planning
	FALSE	TRUE	FALSE
Mentoring programs		Education	Legal support
	TRUE	FALSE	FALSE
Industry partnerships	Sustainability grants		Help finding funding
	FALSE	TRUE	TRUE

```
sum(p_adj_kw < 0.05)
```

[1] 5

Hm. The results are a little surprising. Only five solutions are “divisive” according to this test. But maybe it’s not surprising, if the whole point of doing ordinal regression is that it’s more sensitive than a non-parametric test.

## Plot emms

Plot the results.

```

emm_clean <- summary(all_means) %>%
  rename(mean = mean.class,
         lwr = asymp.LCL,
         upr = asymp.UCL) %>%

```

```

    mutate(across(c(mean, lwr, upr), as.numeric))

# Use a common ordering of solutions (here, overall mean w equal weighting)
solns_ordered <- summary(emmeans(fit1b, ~ solution, weights = "equal")) %>%
  arrange(emmean) %>% # don't do desc() bc these will be flipped later w coord_flip()
  pull(solution) %>%
  as.character()

```

NOTE: Results may be misleading due to involvement in interactions

```

emm_clean <- emm_clean %>%
  mutate(solution = factor(solution, levels = solns_ordered))

make_plot <- function(df, jc) {
  ggplot(filter(df, job_category == jc),
         aes(x = solution, y = mean)) +
    geom_errorbar(aes(ymin = lwr, ymax = upr),
                  width = .15, linewidth = .4) +
    geom_point(size = 3) +
    ylim(c(1, 3)) +
    labs(title = jc, x = NULL, y = "Estimated mean rating (0-3)") +
    coord_flip() +                               # solutions run down the y-axis
    theme(
      plot.title = element_text(face = "bold"),
      axis.text.x = element_text(
        size = 12
      ),
      axis.text.y = element_text(
        size = 12
      ),
      panel.background = element_blank(),
      panel.grid =
        element_line(
          linetype = "solid",
          color = "gray90"
        ),
      plot.margin = unit(c(0.3, 0.3, 0.3, 0.3), "cm")
    )
}

plots <- lapply(unique(emm_clean$job_category),

```

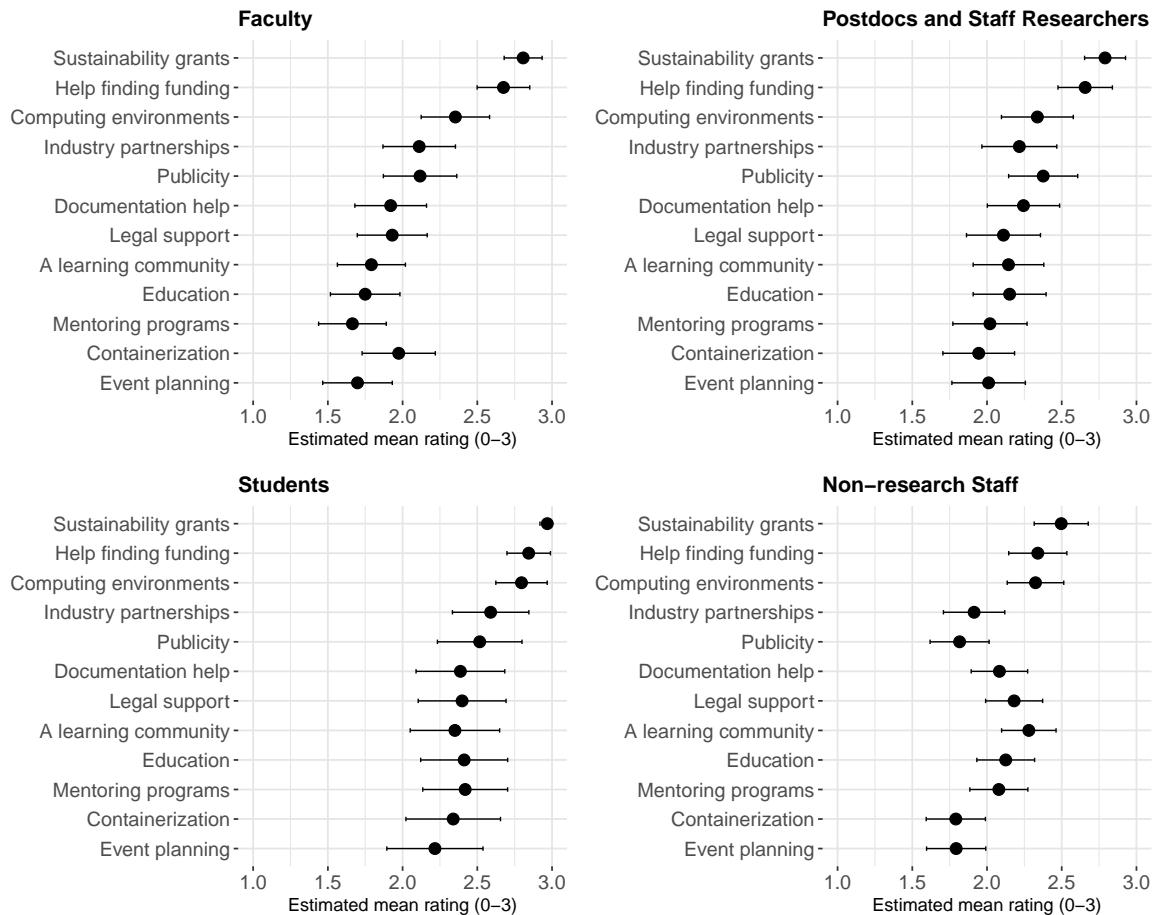
```

make_plot, df = emm_clean)

composite_plot <- wrap_plots(plots, ncol = 2)

composite_plot

```



```
save_plot("solns_points1.tiff", 12, 10, p=composite_plot)
```

Let's try combining them all on one plot.

```

soln_levels <- levels(emm_clean$solution)
interleaved <- as.vector(rbind(paste0(soln_levels, "_sp"), soln_levels))
interleaved[length(interleaved)+1] <- "padding_sp"

```

```

# Define a position dodge object to ensure points and error bars align
pd <- position_dodge(width = 0.6)

# one stripe per real category row
bg <- tibble(cat = factor(interleaved, levels = interleaved)) %>%
  mutate(
    ymin = as.numeric(cat) - 0.5,
    ymax = as.numeric(cat) + 0.5
  )
bg_even <- dplyr::filter(bg, row_number() %% 2 == 0)
bg_odd  <- dplyr::filter(bg, row_number() %% 2 == 1)

# Create the single, combined plot
p_final <- ggplot(emm_clean,
  aes(x = solution, y = mean,
      color = job_category,
      shape = job_category,
      group = job_category)) +
# It's important that these rectangles are above the points and
# errors bars, so they'll be the bottom layer on the plot
  geom_rect(data = bg_odd,
            aes(xmin = ymin, xmax = ymax, ymin = -Inf, ymax = Inf),
            inherit.aes = FALSE, fill = "#f8f8f8", color = NA) +
  geom_rect(data = bg_even,
            aes(xmin = ymin, xmax = ymax, ymin = -Inf, ymax = Inf),
            inherit.aes = FALSE, fill = "#e6e6e6", color = NA) +
  geom_hline(yintercept = seq(1, 3, 0.5), color = "gray90") +
  geom_errorbar(aes(ymin = lwr, ymax = upr),
                width = 0.2,
                linewidth = 0.5,
                position = pd) +
  geom_point(size = 5, position = pd) +
  scale_shape_manual(values = c(16, 17, 15, 18)) +
  scale_x_discrete(limits = interleaved, breaks = soln_levels) +
  ylim(c(1, 3)) +
  labs(
    title = "Estimated Mean Rating by Job Category",
    x = NULL,
    y = "Estimated mean rating"
  ) +
  coord_flip() +

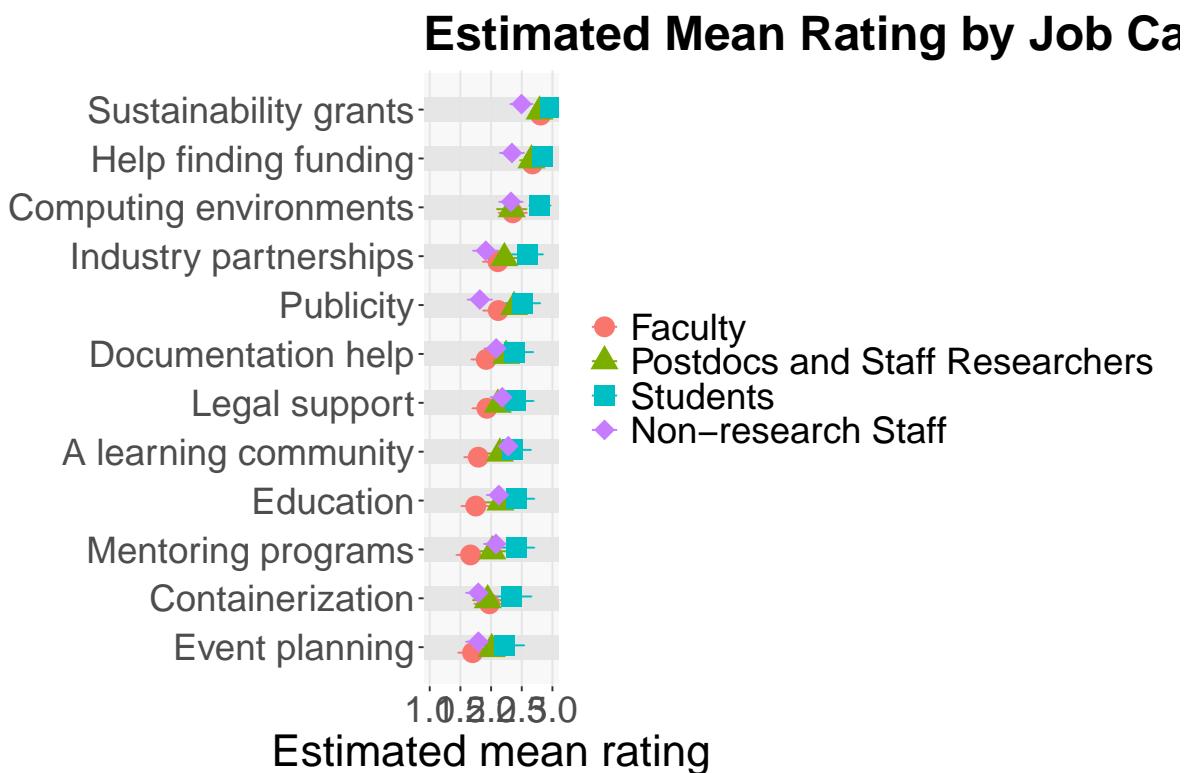
```

```

theme(
  plot.title = element_text(size = 26, hjust = 0, face = "bold"),
  axis.text.x = element_text(size = 20),
  axis.text.y = element_text(size = 20),
  axis.title.x = element_text(size = 24),
  panel.background = element_blank(),
  #panel.grid.major.x = element_line(linetype = "solid", color = "gray90"),
  #panel.grid.major.y = element_line(linetype = "dashed", color = "gray95"),
  plot.margin = unit(c(0.3, 0.3, 0.3, 0.3), "cm"),
  legend.title = element_blank(),
  legend.text=element_text(size=20)
)

p_final

```



```
save_plot("solns_points2.tiff", 16, 10, p=p_final)
```

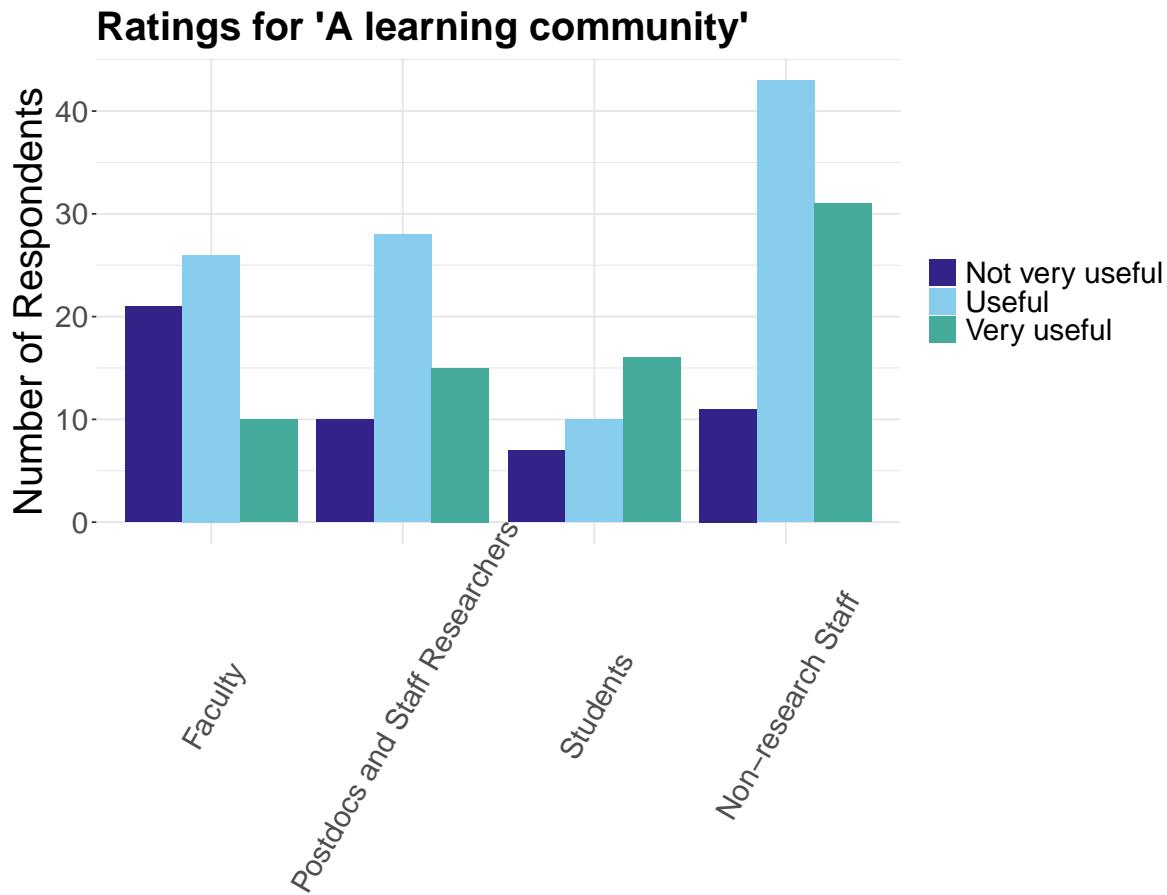
Save the data to file for tweaking the final figure.

```
write_df_to_file(data.frame(soln = solns_ordered), "data_for_plots/solns_ordered.tsv")
write_df_to_file(emm_clean, "data_for_plots/emms_solns.tsv")
```

## Sanity checking: bar plots

I find it very surprising that “a learning community” ranked so low. Let’s look at the rating distribution for each job category, for this solution, from the observed sample.

```
learning_ratings <- grouped_bar_chart(
  df = subset(combined, solution=="A learning community"),
  x_var = "job_category",
  fill_var = "utility",
  title = "Ratings for 'A learning community' ")
learning_ratings
```



```
save_plot("solns_learning_comm.tiff", 12, 10, p=learning_ratings)
```

Ok, it's a messy plot but whatever. It shows that a lot of non-research staff selected “useful” or “very useful”.

## Session Info

```
sessionInfo()
```

```
R version 4.4.2 (2024-10-31)
Platform: aarch64-apple-darwin20
Running under: macOS 26.1
```

```

Matrix products: default
BLAS: /Library/Frameworks/R.framework/Versions/4.4-arm64/Resources/lib/libRblas.0.dylib
LAPACK: /Library/Frameworks/R.framework/Versions/4.4-arm64/Resources/lib/libRlapack.dylib; /Library/Frameworks/R.framework/Versions/4.4-arm64/Resources/lib/libRblas.0.dylib

locale:
[1] C.UTF-8/C.UTF-8/C.UTF-8/C/C.UTF-8/C.UTF-8

time zone: America/Los_Angeles
tzcode source: internal

attached base packages:
[1] tools      grid       stats      graphics   grDevices datasets  utils
[8] methods    base

other attached packages:
[1] treemapify_2.5.6      tidyverse_1.3.1          svglite_2.2.1
[4] stringr_1.5.1         scales_1.4.0            readr_2.1.5
[7] pwr_1.3-0              patchwork_1.3.2        ordinal_2023.12-4.1
[10] lme4_1.1-37           Matrix_1.7-1           languageserver_0.3.16
[13] here_1.0.1             gtools_3.9.5            ggforce_0.5.0
[16] FSA_0.10.0             fpc_2.2-13            forcats_1.0.0
[19] factoextra_1.0.7      ggplot2_3.5.2          emmeans_1.11.2
[22] dplyr_1.1.4            corrplot_0.95          ComplexHeatmap_2.22.0
[25] cluster_2.1.8.1       BiocManager_1.30.26

loaded via a namespace (and not attached):
[1] Rdpack_2.6.4          rlang_1.1.6            magrittr_2.0.3
[4] clue_0.3-66            getoptLong_1.0.5       matrixStats_1.5.0
[7] compiler_4.4.2          flexmix_2.3-20          systemfonts_1.2.3
[10] png_0.1-8              callr_3.7.6            vctrs_0.6.5
[13] pkgconfig_2.0.3         shape_1.4.6.1          crayon_1.5.3
[16] fastmap_1.2.0          labeling_0.4.3         utf8_1.2.6
[19] rmarkdown_2.29          ggrepel_0.10.2         tzdb_0.5.0
[22] ps_1.9.1               nloptr_2.2.1           purrr_1.1.0
[25] xfun_0.53              modeltools_0.2-24      jsonlite_2.0.0
[28] tweenr_2.0.3            parallel_4.4.2         prabclus_2.3-4
[31] R6_2.6.1                stringi_1.8.7          RColorBrewer_1.1-3
[34] boot_1.3-31             diptest_0.77-2          numDeriv_2016.8-1.1
[37] estimability_1.5.1     Rcpp_1.1.0              iterators_1.0.14
[40] knitr_1.50              IRanges_2.40.1          splines_4.4.2
[43] nnet_7.3-19             tidyselect_1.2.1        yaml_2.3.10
[46] doParallel_1.0.17       codetools_0.2-20        processx_3.8.6

```

```
[49] lattice_0.22-6          tibble_3.3.0           withr_3.0.2
[52] evaluate_1.0.4          polyclip_1.10-7       xml2_1.4.0
[55] circlize_0.4.16         mclust_6.1.1           kernlab_0.9-33
[58] pillar_1.11.0           renv_1.1.5             foreach_1.5.2
[61] stats4_4.4.2            reformulas_0.4.1      generics_0.1.4
[64] rprojroot_2.1.1         S4Vectors_0.44.0       hms_1.1.3
[67] minqa_1.2.8             xtable_1.8-4           class_7.3-22
[70] glue_1.8.0               robustbase_0.99-4-1    mvtnorm_1.3-3
[73] rbibutils_2.3            colorspace_2.1-1        nlme_3.1-166
[76] cli_3.6.5                textshaping_1.0.1       gtable_0.3.6
[79] DEoptimR_1.1-4           digest_0.6.37          BiocGenerics_0.52.0
[82] ucminf_1.2.2              ggrepel_0.9.6           rjson_0.2.23
[85] farver_2.1.2              htmltools_0.5.8.1      lifecycle_1.0.4
[88] GlobalOptions_0.1.2      MASS_7.3-61
```