Day Three: Data Analysis

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Pre-introduction

While everyone is getting situated and/or cloning the course materials, pull up `feedback_cleaner.R`. As a review of day 3, walk through the different parts of the script, and ask the students to describe to you what each piece does. For example,

```
dat$timestamp <- sub(' [0-9]+:[0-9]+:[0-9]+', '', dat$timestamp)
dat$timestamp <- as.Date(dat$timestamp, "%m/%d/%Y")
```

is code that reformats ISO timestamps so that R can read them as date-type values.

Introduction

analysis generally procedes in two steps:

1. exploratory data analysis
2. statistical inference

our treatment of graphing owes a lot to the Grammar of Graphics

Summarizing

let's load in some data about D-Lab feedback

```
load('data/feedback.Rda')
str(dat)
```

```
## 'data.frame':    1062 obs. of  14 variables:
##  $ timestamp              : Date, format: "2015-04-23" "2015-04-23" ...
##  $ course.delivered       : int  7 7 7 6 7 6 3 6 5 7 ...
##  $ instructor.communicated: int  6 7 5 6 7 6 2 4 4 7 ...
##  $ hear                   : Factor w/ 51 levels "-","a colleague",..: 19 19 19 34 13 NA 24 19 24 31
##  $ interest               : int  7 7 7 6 6 7 6 7 7 7 ...
##  $ department             : Factor w/ 27 levels "African American Studies",..: NA NA NA NA NA NA NA
##  $ verbs                  : chr  "This was a helpful workshop. \n\nKelly was a clear instructor and
##  $ useful                 : int  7 7 7 6 6 6 3 7 4 7 ...
##  $ gender                 : Factor w/ 3 levels "Female/Woman",..: 2 2 NA 1 1 2 2 NA 1 1 ...
##  $ ethnicity              : chr  "Asian American" "White" "White" "White" ...
##  $ outside.barriers       : int  2 1 1 3 1 1 1 NA 1 1 ...
##  $ inside.barriers        : int  1 1 1 1 1 1 1 NA 1 1 ...
##  $ what.barriers          : chr  NA NA NA NA ...
##  $ position               : Factor w/ 23 levels "Academic staff title",..: 20 4 4 4 9 2 14 NA 15 20
```

R provides two easy/simple summary functions in the base package

```
summary(dat)
```

```
##    timestamp          course.delivered instructor.communicated
##  Min.   :2014-08-19   Min.   :1.000    Min.   :1.000
##  1st Qu.:2014-11-05   1st Qu.:6.000    1st Qu.:6.000
##  Median :2015-01-30   Median :7.000    Median :7.000
##  Mean   :2015-01-22   Mean   :6.251    Mean   :6.257
##  3rd Qu.:2015-04-03   3rd Qu.:7.000    3rd Qu.:7.000
##  Max.   :2015-06-22   Max.   :7.000    Max.   :7.000
##
##                                       hear        interest
##  Email from the D-Lab mailing list     :340   Min.   :1.0
##  Found it on the D-Lab website         :278   1st Qu.:6.0
##  Heard about it from a friend/colleague:247   Median :7.0
##  Email from another mailing list       : 99   Mean   :6.6
##  Don't remember                        : 12   3rd Qu.:7.0
##  (Other)                               : 55   Max.   :7.0
##  NA's                                  : 31   NA's   :15
##                department     verbs              useful
##  Public Health      : 81   Length:1062        Min.   :1.00
##  Public Policy      : 44   Class :character   1st Qu.:5.00
##  Sociology          : 38   Mode  :character   Median :6.00
##  Political Science  : 36                      Mean   :6.02
##  Integrative Biology: 28                      3rd Qu.:7.00
##  (Other)            :288                      Max.   :7.00
##  NA's               :547
##                                gender     ethnicity
##  Female/Woman                     :579   Length:1062
##  Male/Man                         :332   Class :character
##  Genderqueer/Gender non-conforming:  1   Mode  :character
##  NA's                             :150
##
##
##
##  outside.barriers inside.barriers what.barriers
##  Min.   :1.000    Min.   :1.000   Length:1062
##  1st Qu.:1.000    1st Qu.:1.000   Class :character
##  Median :1.000    Median :1.000   Mode  :character
##  Mean   :2.073    Mean   :1.259
##  3rd Qu.:3.000    3rd Qu.:1.000
##  Max.   :5.000    Max.   :5.000
##  NA's   :167      NA's   :175
##                            position
##  PhD student, dissertation stage: 41
##  PhD student, pre-dissertation  : 33
##  Visiting fellow or researcher  : 24
##  Masters student                : 22
##  Undergraduate student          : 21
##  (Other)                        : 64
##  NA's                           :857
```

```
table(dat$department)
```

```
##
##  African American Studies  Ag & Resource Econ & Pol
##                        24                        23
##              Anthropology   App Sci & Tech Grad Grp
##                        12                        10
##    Biostatistics Grad Grp  City & Regional Planning
##                         8                        20
##                 Economics                 Education
##                        23                        26
##  Energy & Resources Group   Env Sci, Policy, & Mgmt
##                        14                        17
##   Ethnic Studies Grad Grp                   History
##                         1                        17
## Industrial Eng & Ops Rsch               Information
##                         4                         9
##       Integrative Biology              JSP Grad Pgm
##                        28                         6
##                       Law               Linguistics
##                         9                        11
##                     Music              Neuroscience
##                         3                         4
##         Political Science                Psychology
##                        36                        28
##             Public Health             Public Policy
##                        81                        44
##                  Rhetoric    Slavic Languages & Lit
##                        11                         8
##                 Sociology
##                        38
```

think back to day one - how would we make weekdays out of the date variable?

```
dat$wday <- factor(weekdays(dat$timestamp, abbreviate = TRUE),
                   levels = c('Mon','Tue','Wed','Thu','Fri','Sat','Sun')
                   )
summary(dat$wday)
```

```
## Mon Tue Wed Thu Fri Sat Sun
## 168 124 144 323 277  16  10
```

reshape provides a few more ways to aggregate things

```
library(reshape2)
dcast(dat[dat$gender == 'Female/Woman' | dat$gender == 'Male/Man',], department ~ gender)
```

```
## Using wday as value column: use value.var to override.
## Aggregation function missing: defaulting to length
```

```
##                   department Female/Woman Male/Man  NA
## 1   African American Studies            8       16   0
## 2   Ag & Resource Econ & Pol           20        3   0
## 3               Anthropology            9        3   0
## 4    App Sci & Tech Grad Grp            6        4   0
## 5     Biostatistics Grad Grp            5        3   0
## 6   City & Regional Planning           12        7   0
## 7                  Economics           16        5   0
## 8                  Education           20        3   0
## 9   Energy & Resources Group           10        3   0
## 10   Env Sci, Policy, & Mgmt           11        5   0
## 11   Ethnic Studies Grad Grp            1        0   0
## 12                   History            9        6   0
## 13 Industrial Eng & Ops Rsch            2        2   0
## 14               Information            2        7   0
## 15       Integrative Biology           20        8   0
## 16              JSP Grad Pgm            5        1   0
## 17                       Law            5        4   0
## 18               Linguistics            8        1   0
## 19                     Music            2        0   0
## 20             Neuroscience            0        4   0
## 21         Political Science           17       18   0
## 22                Psychology           20        8   0
## 23            Public Health           55       19   0
## 24            Public Policy           22       21   0
## 25                 Rhetoric            0       11   0
## 26    Slavic Languages & Lit            7        1   0
## 27                 Sociology           23       12   0
## 28                      <NA>          264      157 150
```

```
dcast(melt(dat, measure.vars = c('course.delivered')), wday ~ 'Delivered', fun.aggregate = mean)
```

```
##   wday Delivered
## 1  Mon  6.309524
## 2  Tue  6.274194
## 3  Wed  6.159722
## 4  Thu  6.077399
## 5  Fri  6.444043
## 6  Sat  6.250000
## 7  Sun  6.600000
```

Plotting

every time you use `base::plot`, Edward Tufte does something unkind to a cute animal

- we'll be using ggplot, R's implementation of the **grammar of graphics**
- in this grammar, you use 'aesthetics' to define how data is mapped to objects the graph space
- each graph space has at least three layers:
  - theme/background/annotations

  - axes
  - objects

- most objects are geometric shapes
- some objects are statistics built on those shapes
- you can stack as many layers as you like

```
install.packages('ggplot2')
```

```
##
## The downloaded binary packages are in
##  /var/folders/rj/8gpcssqd52z9yrqw7f8xxfym0000gn/T//RtmpiQNLx4/downloaded_packages
```

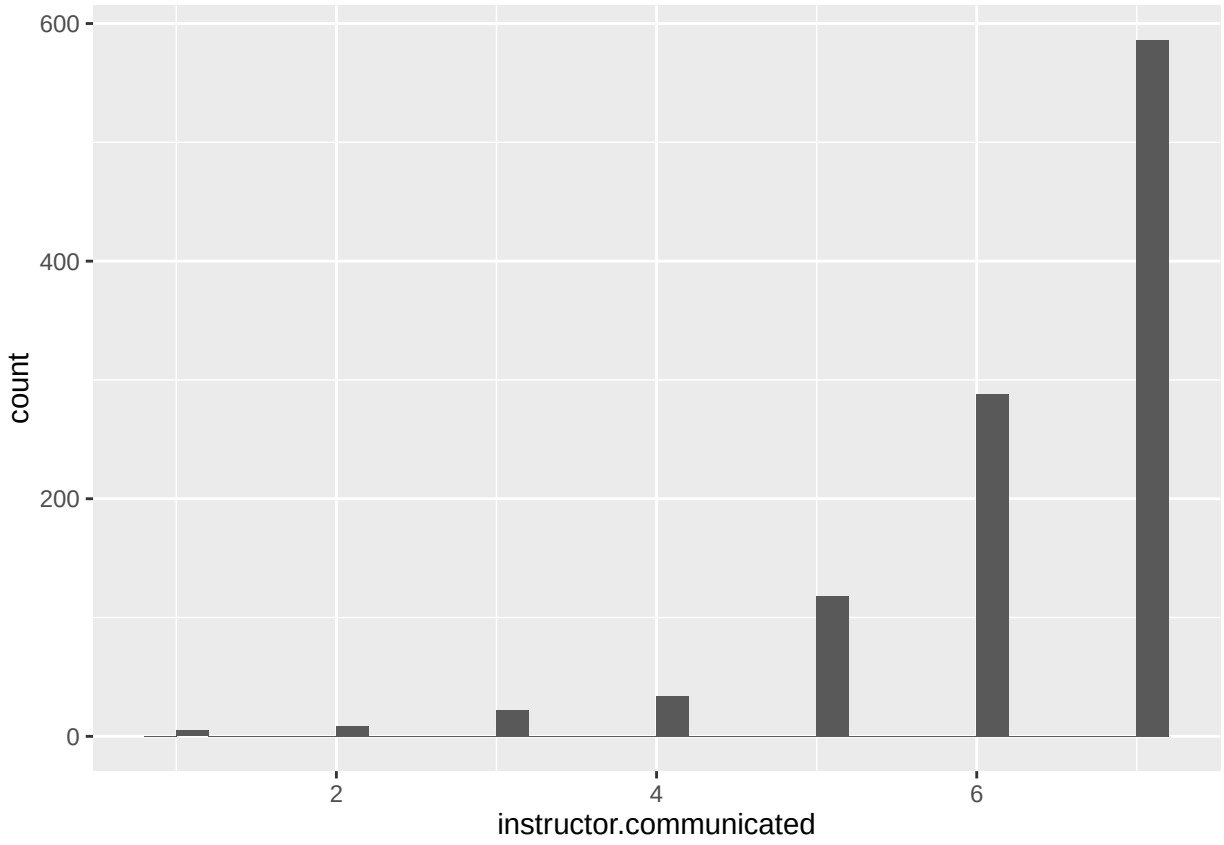
```
library(ggplot2)
```

use qplot for initial poking around

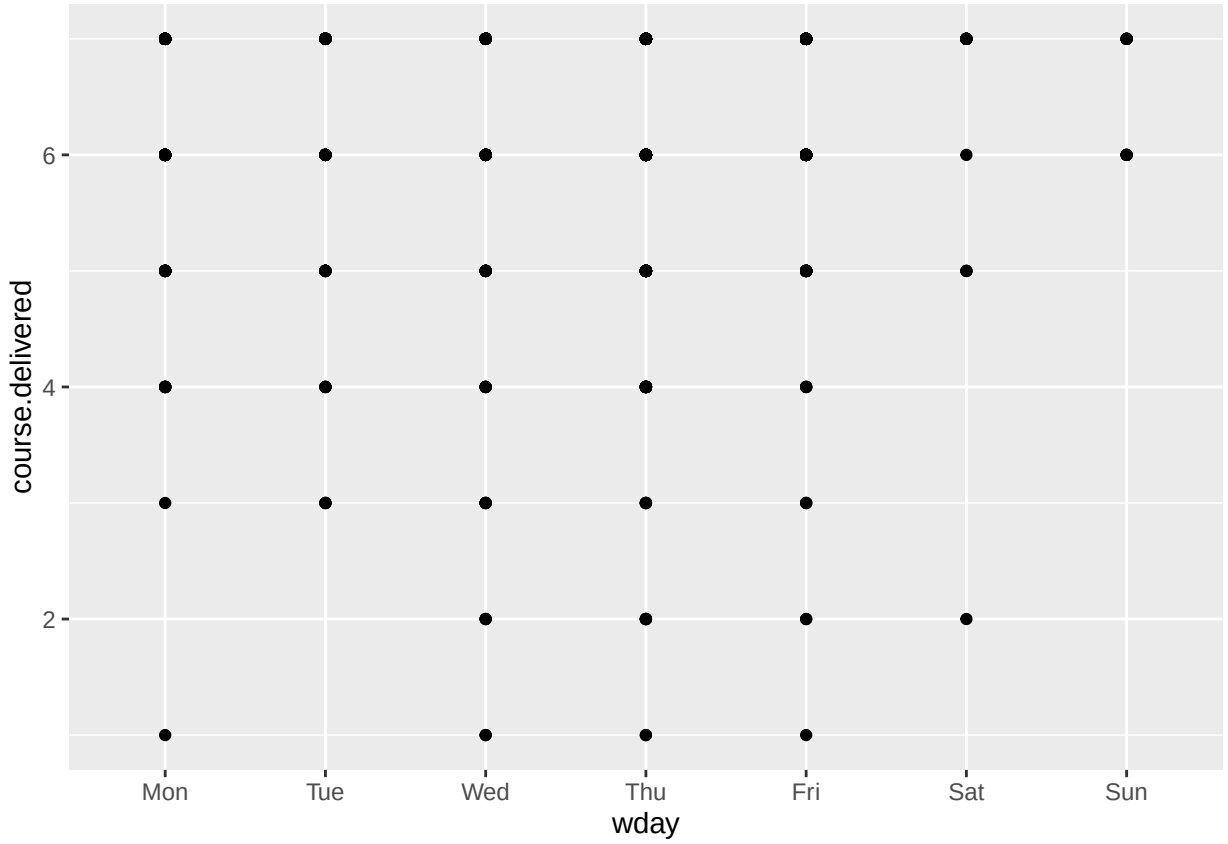
it has very strong intuitions about what you want to see, and is not particularly customizable

```
qplot(instructor.communicated, data = dat)
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

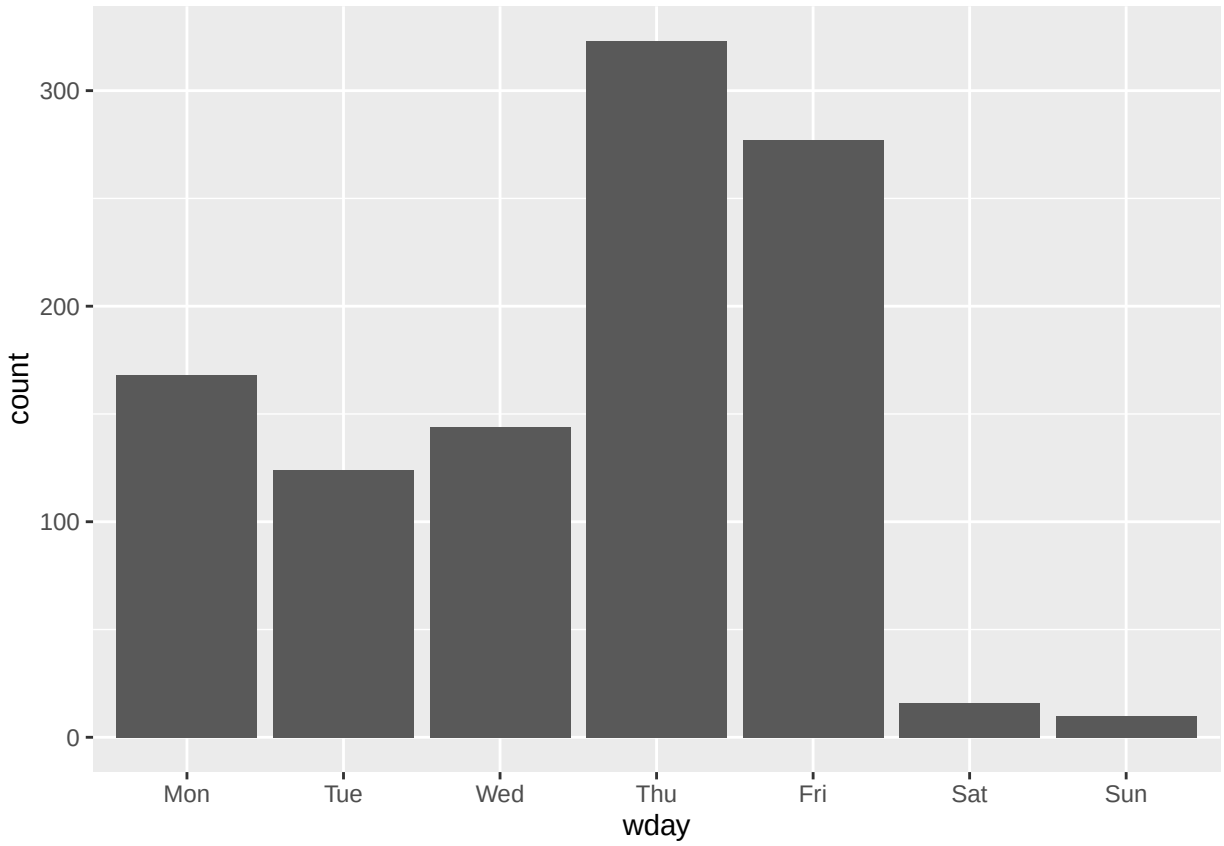


```
qplot(wday, course.delivered, data = dat)
```



for 1D categorical, use bar

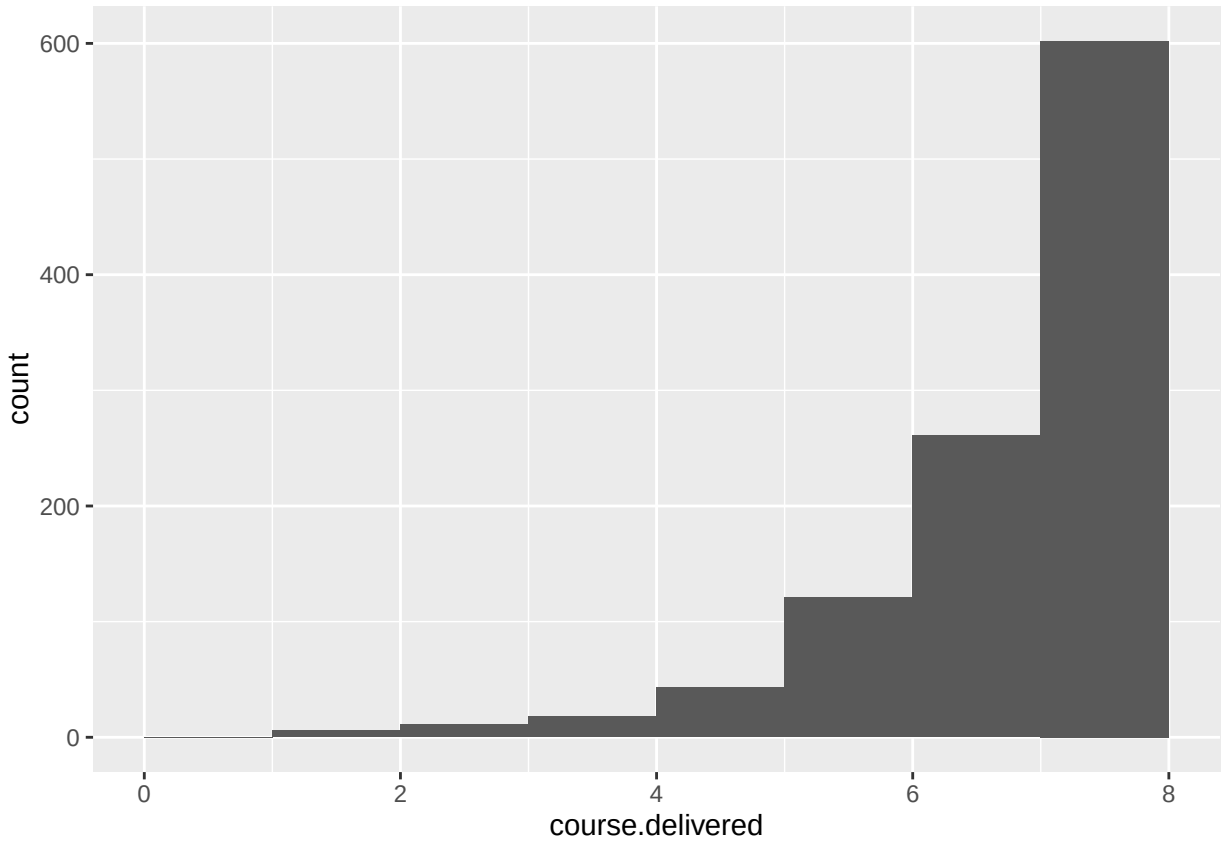
```
ggplot(data=dat, aes(x=wday)) + geom_bar()
```



for 1D continuous, use hist

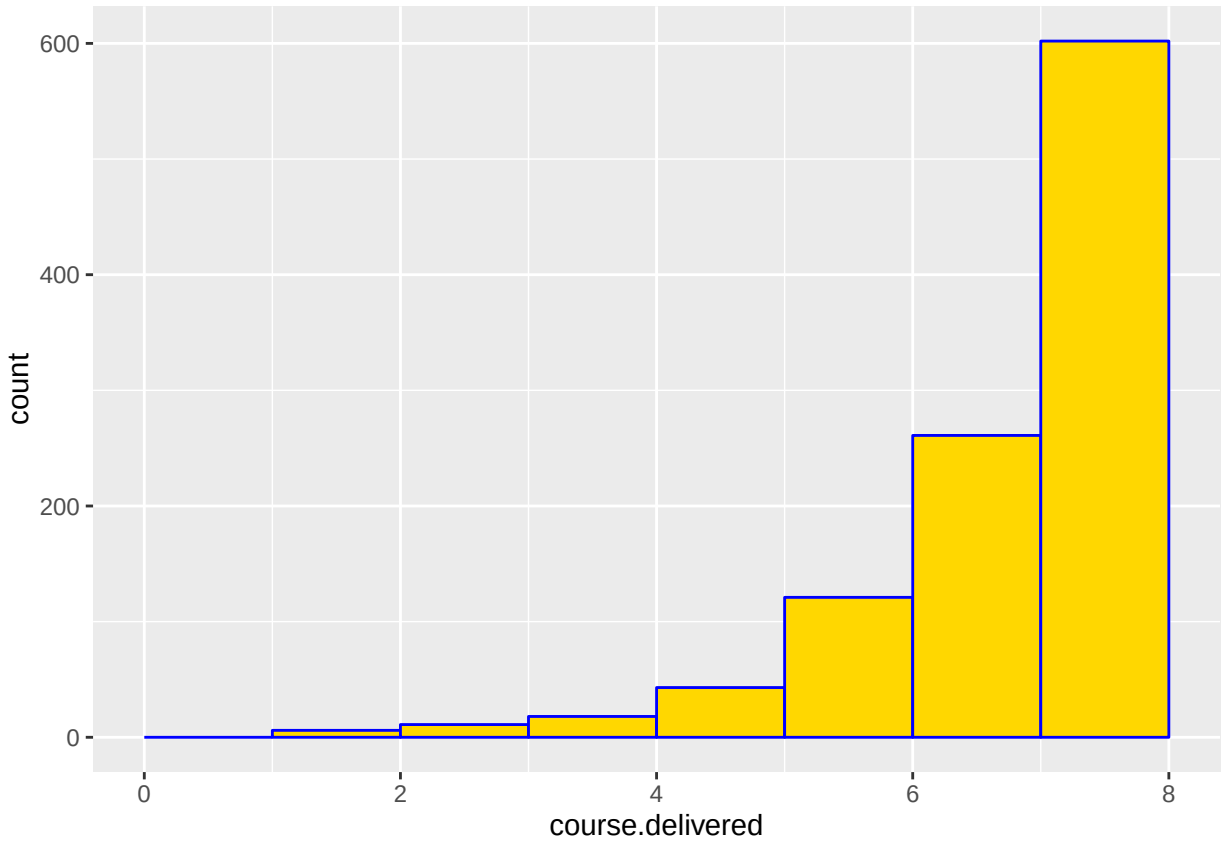
this is really just convenience for `geom_bar(stat = 'bin')`, as opposed to bar plots, whose `stat` is `'count'`

```
ggplot(data=dat, aes(x=course.delivered)) +
  geom_histogram(binwidth=1)
```



you can add color to this plot

```
ggplot(data=dat, aes(x=course.delivered)) +
  geom_histogram(binwidth=1, fill = 'gold', colour= 'blue')
```



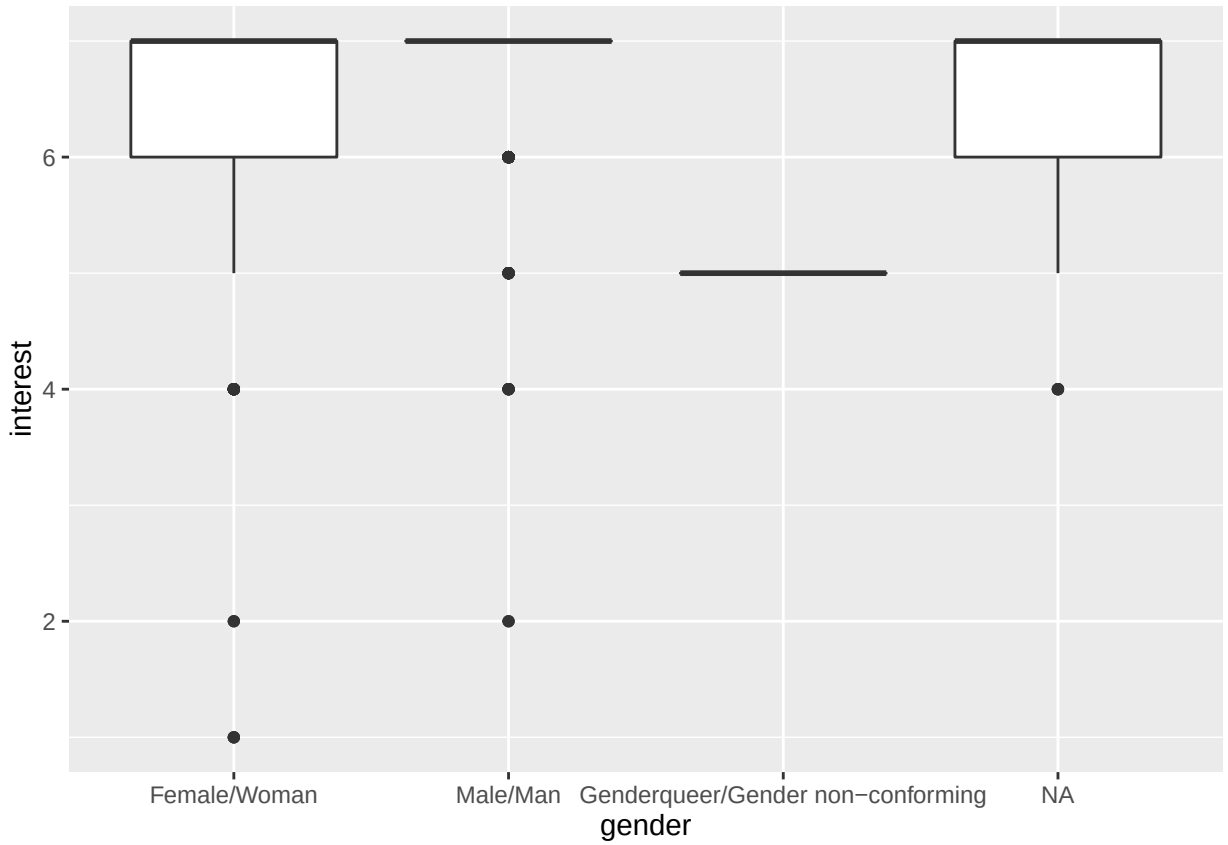
GO BEARS

for many 1D variables, use a box plot

these are handy for a whole bunch of reasons, and you should make them your close associates

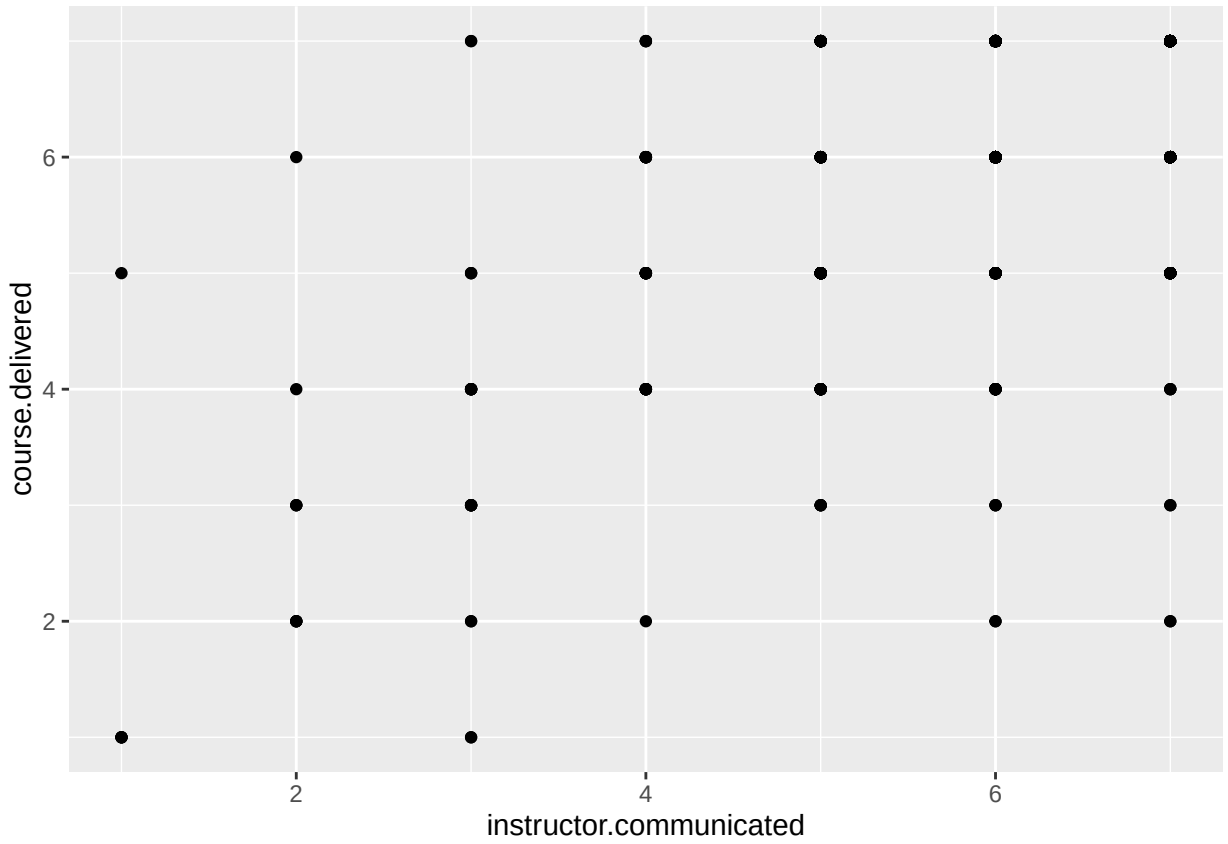
```
ggplot(data=dat, aes(x=gender,y=interest)) + geom_boxplot()
```

```
## Warning: Removed 15 rows containing non-finite values (stat_boxplot).
```



to plot two continuous variables, use points

```
ggplot(data=dat, aes(x=instructor.communicated, y=course.delivered)) + geom_point()
```

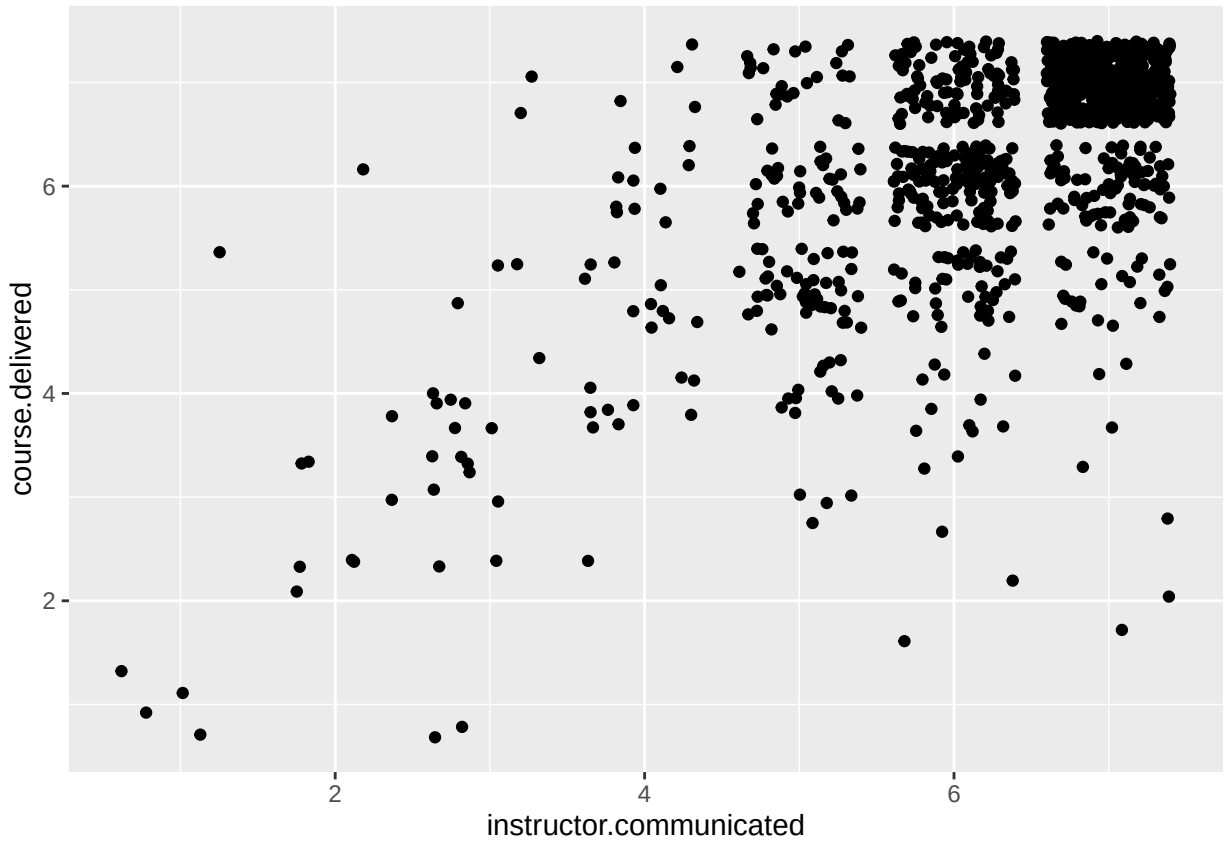


all of these values are discrete, which makes them hard to see

to scatter points randomy, use jitter

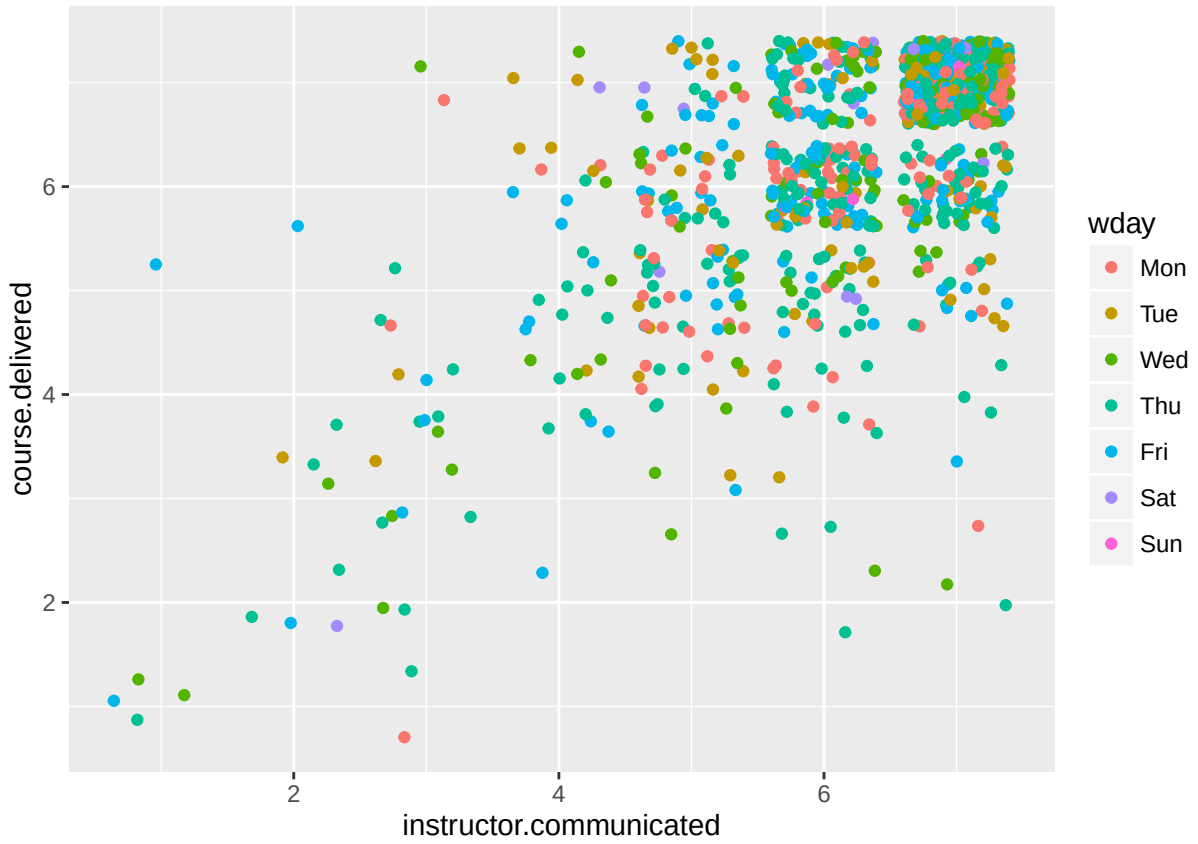
this is really just convenience for `geom_point(position = jitter())`

```
ggplot(data=dat, aes(x=instructor.communicated, y=course.delivered)) +
  geom_jitter()
```



not only can you add color, you can make the color a mapping of other variables

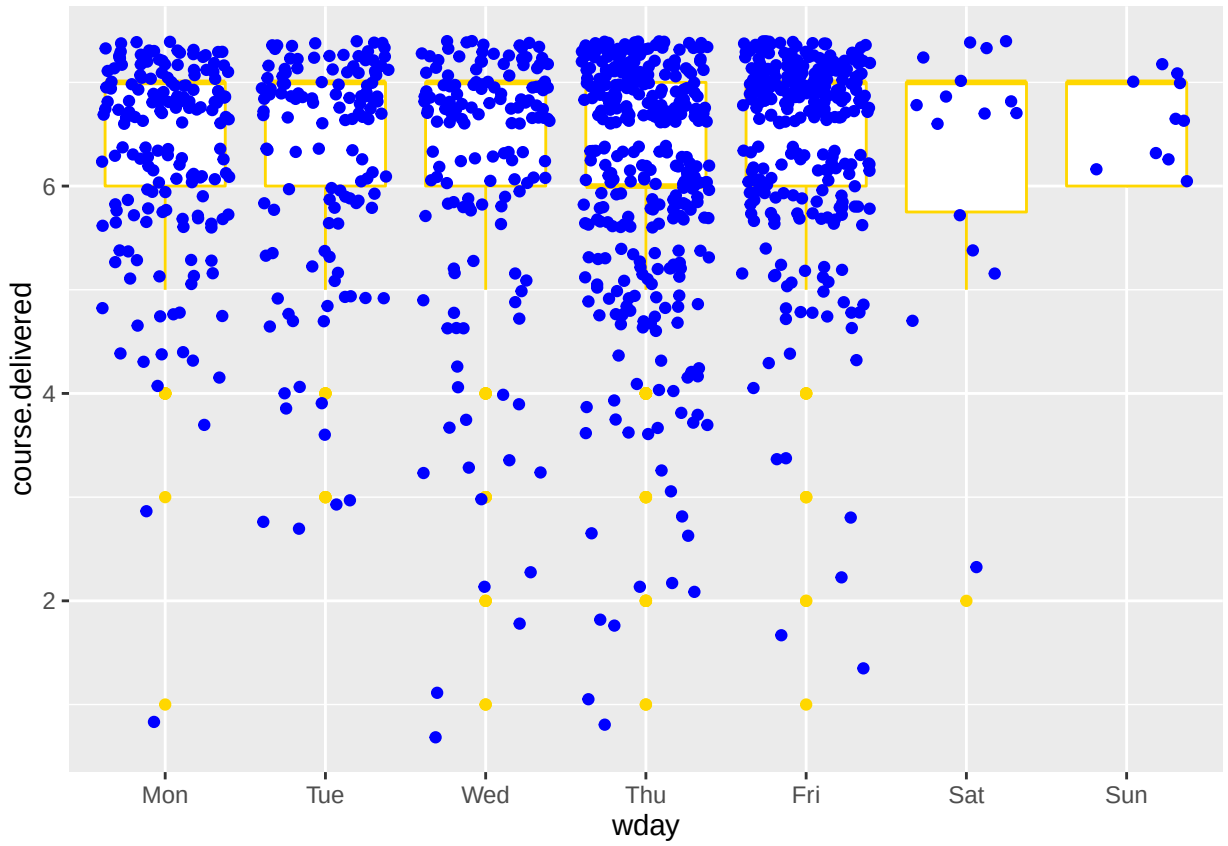
```
ggplot(data=dat, aes(x=instructor.communicated, y=course.delivered)) +
  geom_jitter(aes(colour = wday))
```



the last time we used `colour` it was not an aesthetic - why is it now?

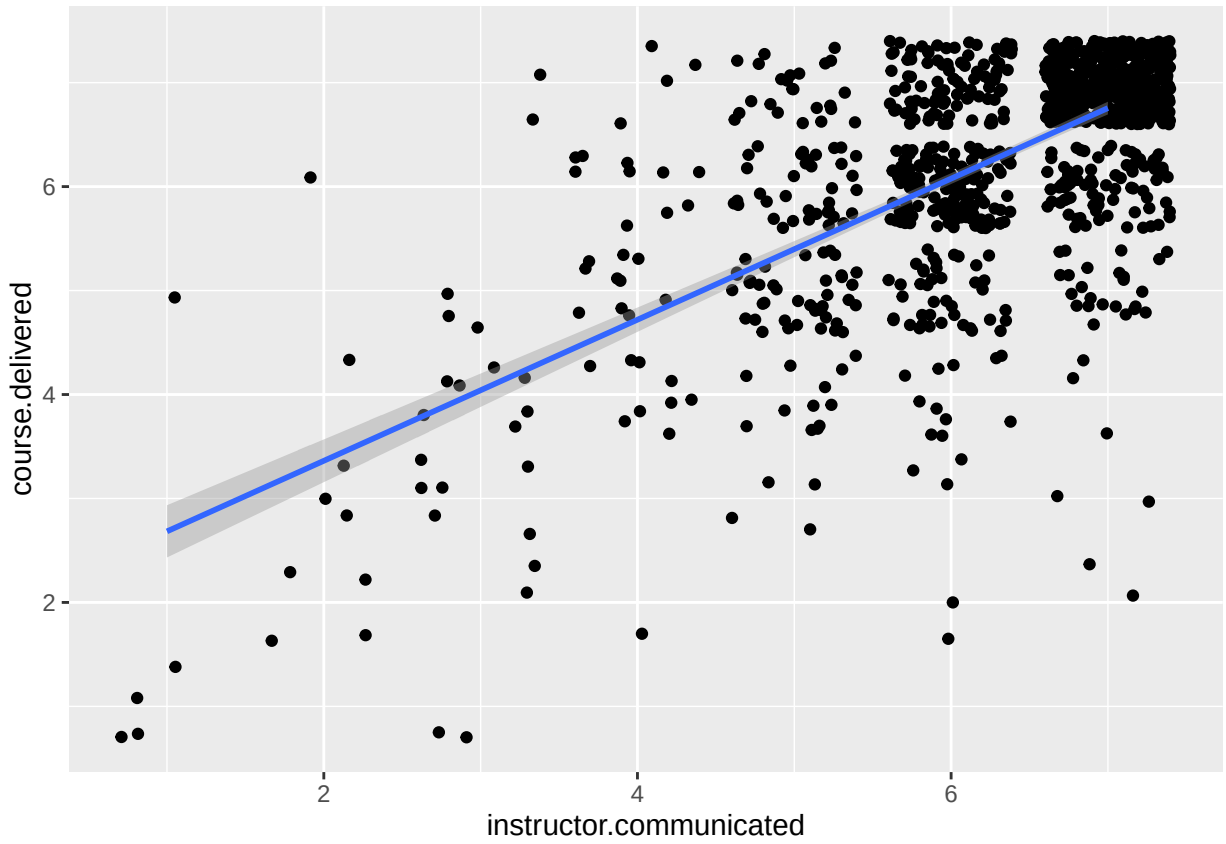
you can stack layers until your eyes hurt

```
ggplot(data=dat, aes(x=wday, y=course.delivered)) +
  geom_boxplot(colour = 'gold') +
  geom_jitter(colour = 'blue')
```



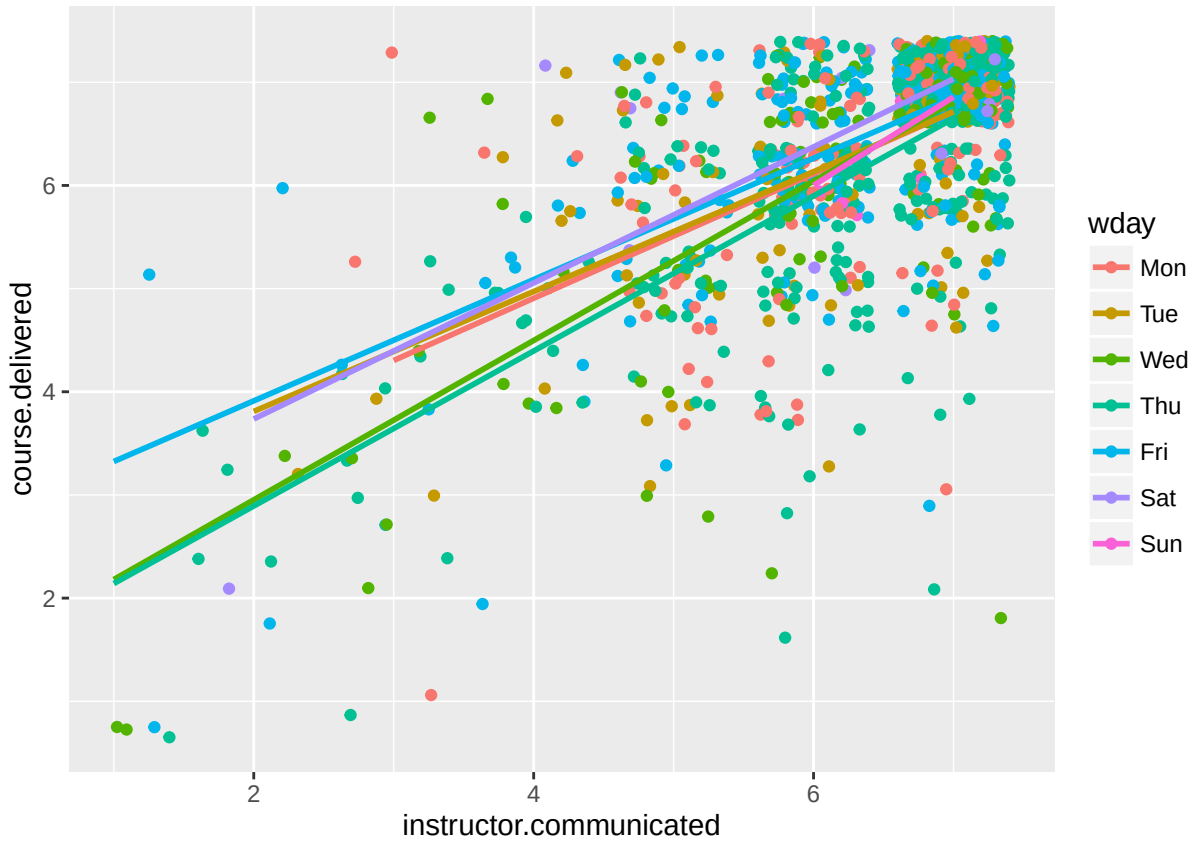
add summary functions with smooth

```
ggplot(data=dat, aes(x=instructor.communicated, y=course.delivered)) +
  geom_jitter() +
  stat_smooth(method = 'lm')
```



if you are using colour as an aesthetic, you'll produce stats for each color

```
ggplot(data=dat, aes(x=instructor.communicated, y=course.delivered, colour = wday)) +
  geom_jitter() +
  stat_smooth(method = 'lm', se = FALSE)
```



good scientists put units on their axes

```
ggplot(data=dat, aes(x=instructor.communicated, y=course.delivered)) +
  geom_jitter() +
  stat_smooth(method = 'lm', colour = 'black') +
  xlab('How well the instructor communicated (1-7)') +
  ylab('How well the course delivered advertised content (1-7)') +
  ggtitle("I have no idea what I'm doing")
```

the general point here is that every single object on this graph is customizable

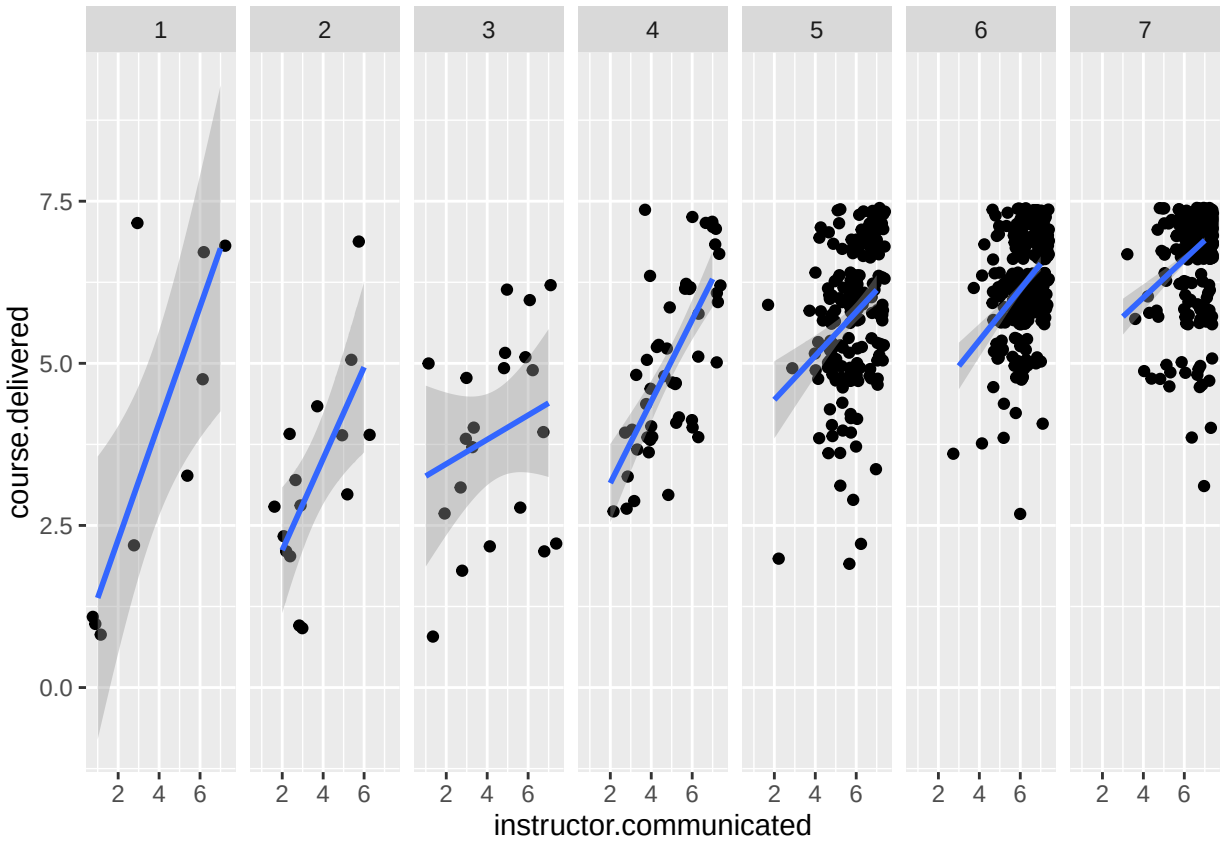
frequent customizations are very simple to add

infrequent customizations will take a lot of tinkering on your part

facetting

often useful for looking at relationships between three variables at the same time

```
ggplot(data=dat, aes(x=instructor.communicated, y=course.delivered)) +
  geom_jitter() +
  stat_smooth(method = 'lm') +
  facet_grid(. ~ useful)
```



Mean testing

a picture is worth 1,000 words, but a p-value is worth a dissertation

basically, inferential statistics is the application of probability theory to decide what is real and what isn't

we'll start by trying to tell whether differences between group summaries are real

t.test with two vectors (default method)

```
t.test(dat$inside.barriers, dat$outside.barriers)
```

```
##
##  Welch Two Sample t-test
##
## data:  dat$inside.barriers and dat$outside.barriers
## t = -16.638, df = 1356.8, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.9092224 -0.7174269
## sample estimates:
## mean of x mean of y
##  1.259301  2.072626
```

note that R takes care of the defaults for you - what it is really computing is 't.test(dat$inside.barriers, dat$outside.barriers, alternative = "two.sided", paired = FALSE, var.equal = FALSE, mu = 0, conf.level = 0.95)

how would you find this out for yourself?

t.test with subsets of one vector (default method)

```
t.test(dat$outside.barriers[dat$gender == "Male/Man"], dat$outside.barriers[dat$gender == "Female/Woman
```

```
##
##  Welch Two Sample t-test
##
## data:  dat$outside.barriers[dat$gender == "Male/Man"] and dat$outside.barriers[dat$gender == "Female/
## t = -6.9925, df = 748.19, p-value = 5.993e-12
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.7650033 -0.4296142
## sample estimates:
## mean of x mean of y
##  1.702875  2.300184
```

recall that we mentioned inconsistency on day one - here it is, and in a big way

t.test with S3 method

```
t.test(outside.barriers ~ gender, data = dat, subset = dat$gender %in% c("Male/Man", "Female/Woman"))
```

```
##
##  Welch Two Sample t-test
##
## data:  outside.barriers by gender
## t = 6.9925, df = 748.19, p-value = 5.993e-12
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.4296142 0.7650033
## sample estimates:
## mean in group Female/Woman     mean in group Male/Man
##                   2.300184                   1.702875
```

aov

first, you would think anova would be called by `anova`, but that's reserved for conducting F-tests on lm objects

second, you really shouldn't be using anova, but if you must do it in R, the syntax looks like this

> side note - ANOVA was invented by Ron Fisher to make it easy to do linear models with only a pencil and paper, and has been superceded by regression since the advent of computation in the 70s

```
aov(outside.barriers ~ gender, data = dat)
```

```
## Call:
##    aov(formula = outside.barriers ~ gender, data = dat)
##
## Terms:
##                     gender Residuals
## Sum of Squares    79.3444 1363.4374
## Deg. of Freedom         2       854
##
## Residual standard error: 1.263539
## Estimated effects may be unbalanced
## 205 observations deleted due to missingness
```

this isn't particularly helpful, but remember that it is an object, and we can call other, more helpful functions, on that object

remember our old friend `summary`? it works on almost everything

```
model.1 <- aov(outside.barriers ~ gender, data = dat)
summary(model.1)
```

```
##              Df Sum Sq Mean Sq F value   Pr(>F)
## gender        2   79.3   39.67   24.85 3.24e-11 ***
## Residuals   854 1363.4    1.60
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 205 observations deleted due to missingness
```

that's a little better - but what about post-hoc testing?

```
TukeyHSD(model.1)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = outside.barriers ~ gender, data = dat)
##
## $gender
##                                                       diff        lwr
## Male/Man-Female/Woman                           -0.5973088 -0.8078392
## Genderqueer/Gender non-conforming-Female/Woman   2.6998158 -0.2694533
## Genderqueer/Gender non-conforming-Male/Man       3.2971246  0.3258507
##                                                       upr    p adj
## Male/Man-Female/Woman                           -0.3867784 0.000000
## Genderqueer/Gender non-conforming-Female/Woman   5.6690850 0.083531
## Genderqueer/Gender non-conforming-Male/Man       6.2683985 0.025285
```

> side note - apparently Stata stores all of the models that you generate, whether you assign them names or not; in R, you must explicitly give your models names or they will disappear into the ether

linear models

mean tests are really just a subset of linear models where your predictor is a category

cor.test (Pearson)

earlier, we were looking at differences between the means of two variables

but those variables were both continuous, so we can ask whether they are related

```
cor.test(dat$outside.barriers, dat$inside.barriers)
```

```
##
##  Pearson's product-moment correlation
##
## data:  dat$outside.barriers and dat$inside.barriers
## t = 15.558, df = 882, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.4106679 0.5142422
## sample estimates:
##       cor
## 0.4640396
```

okay, so they're related - now what?

lm

this is probably the closest you will get to building a linear model by hand

this means lm is a powerful tool, but you have to know what you're doing

the basic call is the S3 method

```
model.1 <- lm(inside.barriers ~ outside.barriers, data = dat)
summary(model.1)
```

```
##
## Call:
## lm(formula = inside.barriers ~ outside.barriers, data = dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.98483 -0.24569  0.00069  0.00069  3.01517
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)       0.75292    0.03842   19.60   <2e-16 ***
## outside.barriers  0.24638    0.01584   15.56   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.6041 on 882 degrees of freedom
##   (178 observations deleted due to missingness)
## Multiple R-squared:  0.2153, Adjusted R-squared:  0.2144
## F-statistic:   242 on 1 and 882 DF,  p-value: < 2.2e-16
```

R automatically one-hot encodes your categories

```
model.2 <- lm(inside.barriers ~ outside.barriers + department, data = dat)
summary(model.2)
```

```
##
## Call:
## lm(formula = inside.barriers ~ outside.barriers + department,
##     data = dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.20049 -0.36011 -0.04989  0.17705  2.91702
##
## Coefficients:
##                                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)                         0.91782    0.14467   6.344 5.57e-10
## outside.barriers                    0.27713    0.02492  11.122  < 2e-16
## departmentAg & Resource Econ & Pol -0.50167    0.19758  -2.539   0.0115
## departmentAnthropology             -0.05175    0.25719  -0.201   0.8406
## departmentApp Sci & Tech Grad Grp   0.11828    0.26693   0.443   0.6579
## departmentBiostatistics Grad Grp   -0.06243    0.26679  -0.234   0.8151
## departmentCity & Regional Planning -0.20133    0.20909  -0.963   0.3361
## departmentEconomics                -0.33051    0.19965  -1.655   0.0986
## departmentEducation                -0.10298    0.19602  -0.525   0.5996
## departmentEnergy & Resources Group -0.44436    0.24646  -1.803   0.0721
## departmentEnv Sci, Policy, & Mgmt  -0.04236    0.21656  -0.196   0.8450
## departmentEthnic Studies Grad Grp  -0.47207    0.66073  -0.714   0.4753
## departmentHistory                   0.16488    0.21638   0.762   0.4465
## departmentIndustrial Eng & Ops Rsch -0.22207   0.35128  -0.632   0.5276
## departmentInformation              -0.21906    0.25570  -0.857   0.3921
## departmentIntegrative Biology      -0.32510    0.18972  -1.714   0.0873
## departmentJSP Grad Pgm              0.09721    0.35124   0.277   0.7821
## departmentLaw                      -0.37970    0.25570  -1.485   0.1383
## departmentLinguistics              -0.28064    0.25582  -1.097   0.2732
## departmentMusic                    -0.47207    0.47727  -0.989   0.3231
## departmentNeuroscience             -0.26423    0.35148  -0.752   0.4526
## departmentPolitical Science        -0.14505    0.17595  -0.824   0.4102
## departmentPsychology               -0.11197    0.18571  -0.603   0.5469
## departmentPublic Health            -0.37200    0.15691  -2.371   0.0182
## departmentPublic Policy            -0.16255    0.17016  -0.955   0.3399
## departmentRhetoric                  0.17521    0.24153   0.725   0.4686
## departmentSlavic Languages & Lit   -0.19495    0.26748  -0.729   0.4665
## departmentSociology                -0.34162    0.17664  -1.934   0.0537
##
## (Intercept)                        ***
## outside.barriers                   ***
```

```
## departmentAg & Resource Econ & Pol  *
## departmentAnthropology
## departmentApp Sci & Tech Grad Grp
## departmentBiostatistics Grad Grp
## departmentCity & Regional Planning
## departmentEconomics                 .
## departmentEducation
## departmentEnergy & Resources Group  .
## departmentEnv Sci, Policy, & Mgmt
## departmentEthnic Studies Grad Grp
## departmentHistory
## departmentIndustrial Eng & Ops Rsch
## departmentInformation
## departmentIntegrative Biology       .
## departmentJSP Grad Pgm
## departmentLaw
## departmentLinguistics
## departmentMusic
## departmentNeuroscience
## departmentPolitical Science
## departmentPsychology
## departmentPublic Health             *
## departmentPublic Policy
## departmentRhetoric
## departmentSlavic Languages & Lit
## departmentSociology                 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6462 on 440 degrees of freedom
##   (594 observations deleted due to missingness)
## Multiple R-squared:  0.2759, Adjusted R-squared:  0.2314
## F-statistic: 6.209 on 27 and 440 DF,  p-value: < 2.2e-16
```

R does not assume you want the full factorial model

```
model.3 <- lm(inside.barriers ~ outside.barriers + department + outside.barriers*department, data = dat)
summary(model.3)
```

```
##
## Call:
## lm(formula = inside.barriers ~ outside.barriers + department +
##     outside.barriers * department, data = dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.75495 -0.25924  0.00000  0.05784  2.80608
##
## Coefficients: (3 not defined because of singularities)
##                                                    Estimate Std. Error
## (Intercept)                                       0.3378995  0.2274560
## outside.barriers                                  0.6042618  0.1072238
```

```
## departmentAg & Resource Econ & Pol                     0.5964070  0.3649460
## departmentAnthropology                                  0.1087024  0.4637595
## departmentApp Sci & Tech Grad Grp                       0.0001286  0.5189858
## departmentBiostatistics Grad Grp                       -0.7015359  0.5198322
## departmentCity & Regional Planning                      0.4121005  0.4931678
## departmentEconomics                                     0.7321813  0.3636619
## departmentEducation                                     0.1234904  0.3435377
## departmentEnergy & Resources Group                      0.6621005  0.4114066
## departmentEnv Sci, Policy, & Mgmt                       0.1485869  0.3921866
## departmentEthnic Studies Grad Grp                      -0.5464231  0.5996170
## departmentHistory                                      -0.1648226  0.3431664
## departmentIndustrial Eng & Ops Rsch                     0.2454338  0.6053634
## departmentInformation                                   0.2750037  0.5174054
## departmentIntegrative Biology                           0.5698762  0.3364553
## departmentJSP Grad Pgm                                 -0.4288086  0.7210600
## departmentLaw                                           0.6621005  0.3866430
## departmentLinguistics                                   0.9274066  0.4800139
## departmentMusic                                        -0.5464231  0.4334402
## departmentNeuroscience                                  0.6621005  0.9235061
## departmentPolitical Science                             0.3541044  0.2943577
## departmentPsychology                                    0.6858647  0.3178332
## departmentPublic Health                                 0.4345019  0.2604548
## departmentPublic Policy                                 0.2930528  0.2905775
## departmentRhetoric                                     -7.3378995  1.3298262
## departmentSlavic Languages & Lit                        0.0578387  0.2557124
## departmentSociology                                     0.6621005  0.3254963
## outside.barriers:departmentAg & Resource Econ & Pol    -0.4947727  0.1356053
## outside.barriers:departmentAnthropology                -0.1819317  0.1627797
## outside.barriers:departmentApp Sci & Tech Grad Grp      0.0013720  0.2240160
## outside.barriers:departmentBiostatistics Grad Grp       0.3230109  0.2478656
## outside.barriers:departmentCity & Regional Planning    -0.3542618  0.3517710
## outside.barriers:departmentEconomics                   -0.5880893  0.1732220
## outside.barriers:departmentEducation                   -0.1930649  0.1370691
## outside.barriers:departmentEnergy & Resources Group    -0.6042618  0.1858492
## outside.barriers:departmentEnv Sci, Policy, & Mgmt     -0.1448023  0.1699881
## outside.barriers:departmentEthnic Studies Grad Grp             NA         NA
## outside.barriers:departmentHistory                      0.1601613  0.1545218
## outside.barriers:departmentIndustrial Eng & Ops Rsch   -0.2709285  0.2621456
## outside.barriers:departmentInformation                 -0.2816812  0.2476624
## outside.barriers:departmentIntegrative Biology         -0.4541714  0.1387724
## outside.barriers:departmentJSP Grad Pgm                 0.3048291  0.3692532
## outside.barriers:departmentLaw                         -0.6042618  0.1815371
## outside.barriers:departmentLinguistics                 -0.6246700  0.2074324
## outside.barriers:departmentMusic                               NA         NA
## outside.barriers:departmentNeuroscience                -0.6042618  0.6850431
## outside.barriers:departmentPolitical Science           -0.2878748  0.1320162
## outside.barriers:departmentPsychology                  -0.4341097  0.1425093
## outside.barriers:departmentPublic Health               -0.4340109  0.1185779
## outside.barriers:departmentPublic Policy               -0.2649761  0.1327705
## outside.barriers:departmentRhetoric                     2.1457382  0.4109273
## outside.barriers:departmentSlavic Languages & Lit              NA         NA
## outside.barriers:departmentSociology                   -0.4996106  0.1372998
##                                                        t value Pr(>|t|)
## (Intercept)                                              1.486 0.138151
```

```
## outside.barriers                                          5.636 3.22e-08 ***
## departmentAg & Resource Econ & Pol                        1.634 0.102964
## departmentAnthropology                                    0.234 0.814794
## departmentApp Sci & Tech Grad Grp                         0.000 0.999802
## departmentBiostatistics Grad Grp                         -1.350 0.177895
## departmentCity & Regional Planning                        0.836 0.403848
## departmentEconomics                                       2.013 0.044719 *
## departmentEducation                                       0.359 0.719428
## departmentEnergy & Resources Group                        1.609 0.108295
## departmentEnv Sci, Policy, & Mgmt                         0.379 0.704979
## departmentEthnic Studies Grad Grp                        -0.911 0.362671
## departmentHistory                                        -0.480 0.631266
## departmentIndustrial Eng & Ops Rsch                       0.405 0.685368
## departmentInformation                                     0.532 0.595352
## departmentIntegrative Biology                             1.694 0.091057 .
## departmentJSP Grad Pgm                                   -0.595 0.552372
## departmentLaw                                             1.712 0.087560 .
## departmentLinguistics                                     1.932 0.054032 .
## departmentMusic                                          -1.261 0.208134
## departmentNeuroscience                                    0.717 0.473811
## departmentPolitical Science                               1.203 0.229669
## departmentPsychology                                      2.158 0.031503 *
## departmentPublic Health                                   1.668 0.096018 .
## departmentPublic Policy                                   1.009 0.313790
## departmentRhetoric                                       -5.518 6.03e-08 ***
## departmentSlavic Languages & Lit                          0.226 0.821167
## departmentSociology                                       2.034 0.042571 *
## outside.barriers:departmentAg & Resource Econ & Pol      -3.649 0.000297 ***
## outside.barriers:departmentAnthropology                  -1.118 0.264358
## outside.barriers:departmentApp Sci & Tech Grad Grp        0.006 0.995116
## outside.barriers:departmentBiostatistics Grad Grp         1.303 0.193236
## outside.barriers:departmentCity & Regional Planning      -1.007 0.314480
## outside.barriers:departmentEconomics                     -3.395 0.000752 ***
## outside.barriers:departmentEducation                     -1.409 0.159722
## outside.barriers:departmentEnergy & Resources Group      -3.251 0.001242 **
## outside.barriers:departmentEnv Sci, Policy, & Mgmt       -0.852 0.394793
## outside.barriers:departmentEthnic Studies Grad Grp           NA       NA
## outside.barriers:departmentHistory                        1.036 0.300571
## outside.barriers:departmentIndustrial Eng & Ops Rsch     -1.034 0.301967
## outside.barriers:departmentInformation                   -1.137 0.256041
## outside.barriers:departmentIntegrative Biology           -3.273 0.001154 **
## outside.barriers:departmentJSP Grad Pgm                   0.826 0.409544
## outside.barriers:departmentLaw                           -3.329 0.000950 ***
## outside.barriers:departmentLinguistics                   -3.011 0.002758 **
## outside.barriers:departmentMusic                             NA       NA
## outside.barriers:departmentNeuroscience                  -0.882 0.378243
## outside.barriers:departmentPolitical Science             -2.181 0.029771 *
## outside.barriers:departmentPsychology                    -3.046 0.002465 **
## outside.barriers:departmentPublic Health                 -3.660 0.000284 ***
## outside.barriers:departmentPublic Policy                 -1.996 0.046612 *
## outside.barriers:departmentRhetoric                       5.222 2.80e-07 ***
## outside.barriers:departmentSlavic Languages & Lit            NA       NA
## outside.barriers:departmentSociology                     -3.639 0.000308 ***
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.586 on 417 degrees of freedom
##   (594 observations deleted due to missingness)
## Multiple R-squared:  0.4357, Adjusted R-squared:  0.368
## F-statistic: 6.439 on 50 and 417 DF,  p-value: < 2.2e-16
```

extract model parameters with $

```
model.1$coefficients
```

```
##      (Intercept) outside.barriers
##        0.7529250        0.2463815
```

```
model.1$coefficients[[2]]
```

```
## [1] 0.2463815
```

this is useful if you want to plot residuals

```
dat$residuals <- model.1$residuals
```

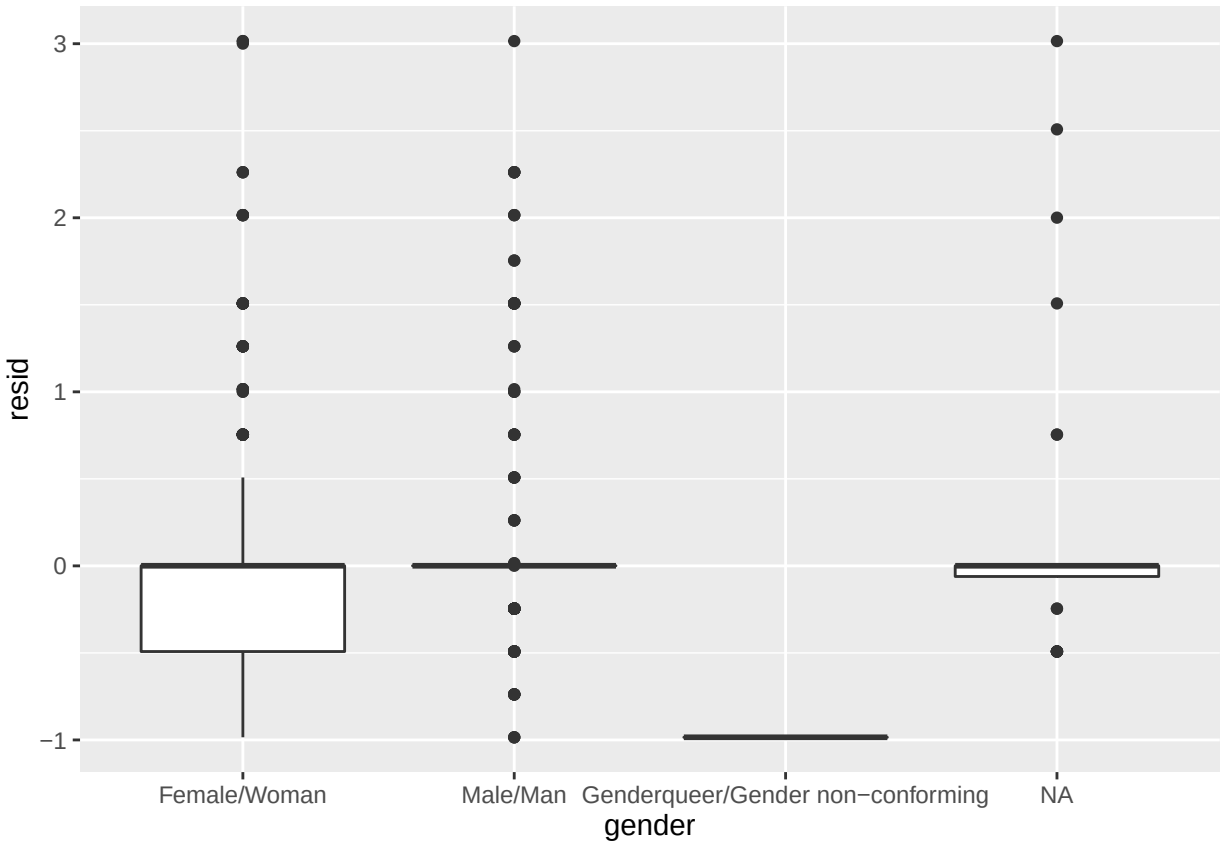
oh boy golly gee gosh darn! remember how we talked about R having casewise deletion + bad indexing? this is one place where it makes your life difficult

we have to do something like this:

```
dat.listwise <- dat[!is.na(dat$inside.barriers) & !is.na(dat$outside.barriers), ]
dat.listwise$resid <- model.1$residuals
```

then we can do this

```
ggplot(data = dat.listwise, aes(x=gender,y=resid)) +
  geom_boxplot()
```



Nonparametric

parametric refers to using means, deviations, and other estimates of population parameters

BUT what if you don't want to make assumptions about the structure of the population?

or what if you **gasp** can't?

ranked variables

a simple case is where means don't have meaning

above we were looking at correlations between Likert variables

all Likerts are really rank variables, which means they don't act like actual number-y numbers

in the real world, a 6 foot tall person is twice as tall as a 3 foot tall person

but is a level '6' really twice as many barriers to access as a '3'?

NOPE

we know that 6 is more than 3, but can't really say how much - in that sense then, a scale of 1-7 is exactly the same thing as a scale of a-g.

median testing ranks

we use Mann-Whitney sums to test that the ranks are centered the same way

```
wilcox.test(dat$outside.barriers, dat$inside.barriers, alternative = "two.sided", paired = FALSE, mu = 0
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  dat$outside.barriers and dat$inside.barriers
## W = 541240, p-value < 2.2e-16
## alternative hypothesis: true location shift is not equal to 0
```

see how this setup looks exactly like a t-test? that's not an accident

correlating ranks

this is just like the `cor.test` you did above, but with `method` set to equal 'spearman' instead of pearson

```
cor.test(dat$outside.barriers, dat$inside.barriers, method = 'spearman')
```

```
## Warning in cor.test.default(dat$outside.barriers, dat$inside.barriers,
## method = "spearman"): Cannot compute exact p-value with ties
```

```
##
##  Spearman's rank correlation rho
##
## data:  dat$outside.barriers and dat$inside.barriers
## S = 63037000, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.4524909
```

rho is pretty close to the r from above

chisq

what if both of your variables are categories? we can test their counts with R's built in `chisq.test` function

i.e. what if we want to know if gender is distributed evenly over departments?

```
chisq.test(dat$gender, dat$department)
```

```
## Warning in chisq.test(dat$gender, dat$department): Chi-squared
## approximation may be incorrect
```

```
##
##  Pearson's Chi-squared test
##
## data:  dat$gender and dat$department
## X-squared = 76.442, df = 26, p-value = 7.326e-07
```

Practice

Assignment

There were a lot of variables in this dataset that we did not look at today:

```
names(data)
```

```
## NULL
```

Choose two of those variables, and explore their distribution and relationship to each other. Can you conclude anything about the D-Lab based on the feedback?

Acknowledgements

Materials taken from:

D-Lab's Feedback Analytics