Example models (abridged)

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## Setup

These are real pilot data, collected on 2014-10-18, exploring people's implicit theories of selfhood, personhood, personal identity, etc. - "Experimental Philosophy"!

Here, we'll focus on trying to predict a subject's comfort with the idea of neuron replacement surgery, in which individual neurons are replaced with "electronic circuits" that function just like neurons. The "comfort" score is a composite score, including responses to questions like "If your doctor recommended this procedure (e.g., to prevent dementia), would you have it done?".

Variables:

* Subj: unique identifier for subject
* Cond: 2 versions of teleporter scenario, C1 (coded as 0) vs. C2 (coded as 1)
* Gender: male or female
* Relig: Judeo-Christian (coded as 1) or not religious (coded as 0)
* EnjoyScifi: how much subj enjoys scifi (range: [-4, +4])
* ThinkOften: how often subj thinks about these thought expts (range: [0, 6])
* Teleporter: comfort with teleporter scenario (range: [-15, +15])
* NeuronRepl: comfort with the idea of neuron replacement surgery scenario (range: [-12, +12])

# Load in packages  
library(ggplot2)  
library(scatterplot3d)  
  
# Load in data  
xphil = read.csv("http://web.stanford.edu/~kweisman/XPhil/xphil\_demo.csv")  
  
# Remove Relig NAs  
xphil = subset(xphil, Religion2 != "NA")  
  
# Recode variables to have shorter names  
xphil$Cond = factor(xphil$Condition, labels = c("C1", "C2"))  
xphil$Relig = factor(xphil$Religion2, labels = c("JC", "None"))  
  
# Set contrasts  
contrasts(xphil$Relig) = c(1,0) # changed

## Single regression (1 predictor)

### One continuous (numeric) predictor

**Research question**: Does a subj's comfort with the idea of neuron replacement surgery depend on how much s/he enjoys science fiction?

# Effect of EnjoyScifi on NeuronRepl  
r1 = lm(NeuronRepl ~ EnjoyScifi, data = xphil); summary(r1)

##   
## Call:  
## lm(formula = NeuronRepl ~ EnjoyScifi, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -13.35 -3.75 1.60 4.30 9.20   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 3.750 0.775 4.84 7.2e-06 \*\*\*  
## EnjoyScifi 0.650 0.284 2.29 0.025 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.56 on 73 degrees of freedom  
## Multiple R-squared: 0.0672, Adjusted R-squared: 0.0544   
## F-statistic: 5.26 on 1 and 73 DF, p-value: 0.0247

*What is the regression equation?*

*What does the intercept mean?*

*What does the coefficient for* EnjoyScifi *mean?*

*How would you write up these results?*

### One discrete (categorical) predictor

**Research question**: Does a subj's comfort with the idea of neuron replacement surgery depend on his/her gender?

# Effect of Gender on NeuronRepl  
r2a = lm(NeuronRepl ~ Gender, data = xphil); summary(r2a)

##   
## Call:  
## lm(formula = NeuronRepl ~ Gender, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -12.63 -4.06 1.37 4.87 7.44   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 3.56 1.00 3.56 0.00066 \*\*\*  
## GenderM 2.07 1.32 1.56 0.12263   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.66 on 73 degrees of freedom  
## Multiple R-squared: 0.0323, Adjusted R-squared: 0.0191   
## F-statistic: 2.44 on 1 and 73 DF, p-value: 0.123

*What is the regression equation?*

*What does the intercept mean?*

*What does the coefficient for* GenderM *mean?*

*What is the mean comfort level for men? For women?*

*How would you write up these results?*

...what about his/her religion?

# Effect of Relig on NeuronRepl  
r2b = lm(NeuronRepl ~ Relig, data = xphil); summary(r2b)

##   
## Call:  
## lm(formula = NeuronRepl ~ Relig, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -12.39 -4.74 1.60 4.92 7.92   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 5.395 0.928 5.81 1.5e-07 \*\*\*  
## Relig1 -1.314 1.321 -0.99 0.32   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.72 on 73 degrees of freedom  
## Multiple R-squared: 0.0134, Adjusted R-squared: -0.000148   
## F-statistic: 0.989 on 1 and 73 DF, p-value: 0.323

*What is the regression equation?*

*What does the intercept mean?*

*What does the coefficient for* Relig1 *mean?*

*What is the mean comfort level for non-religious people? For Judeo-christian people?*

*How would you write up these results?*...what about his/her experimental condition?

# Effect of Cond on NeuronRepl  
r2c = lm(NeuronRepl ~ Cond, data = xphil); summary(r2c)

##   
## Call:  
## lm(formula = NeuronRepl ~ Cond, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -12.34 -4.74 1.66 4.87 7.87   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 5.342 0.929 5.75 1.9e-07 \*\*\*  
## CondC2 -1.207 1.322 -0.91 0.36   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.73 on 73 degrees of freedom  
## Multiple R-squared: 0.0113, Adjusted R-squared: -0.00226   
## F-statistic: 0.833 on 1 and 73 DF, p-value: 0.364

*What is the regression equation?*

*What does the intercept mean?*

*What does the coefficient for* CondC2 *mean?*

*What is the mean comfort level for people in Condition 1? For people in Condition 2?*

## *How would you write up these results?*Multiple regression (≥ 1 predictor)

### Additive models

#### Two continuous predictors

**Research question**: Does a subj's comfort with the idea of neuron replacement surgery depend his/her enjoyment of science fiction, and/or his/her comfort with teleportation (the thought experiment presented immediately prior to this judgment)?

# Effects of EnjoyScifi + Teleporter on NeuronRepl  
r3a = lm(NeuronRepl ~ EnjoyScifi + Teleporter, data = xphil); summary(r3a)

##   
## Call:  
## lm(formula = NeuronRepl ~ EnjoyScifi + Teleporter, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -12.78 -3.83 1.16 4.00 8.46   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 2.6075 0.8519 3.06 0.0031 \*\*  
## EnjoyScifi 0.7481 0.2740 2.73 0.0080 \*\*  
## Teleporter 0.2038 0.0744 2.74 0.0077 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.33 on 72 degrees of freedom  
## Multiple R-squared: 0.155, Adjusted R-squared: 0.132   
## F-statistic: 6.62 on 2 and 72 DF, p-value: 0.00229

*What is the regression equation?*

*What does the intercept mean?*

*What do the coefficients for* EnjoyScifi *and* Teleporter *mean?*

#### *How would you write up these results?*Two categorical predictors

**Research question**: Does a subj's comfort with the idea of neuron replacement surgery depend his/her experimental condition, and/or his/her religion?

# Effects of Cond + Relig on NeuronRepl  
r3b = lm(NeuronRepl ~ Cond + Relig, data = xphil); summary(r3b)

##   
## Call:  
## lm(formula = NeuronRepl ~ Cond + Relig, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -11.78 -4.73 1.32 4.77 8.62   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 6.08 1.16 5.24 1.5e-06 \*\*\*  
## CondC2 -1.30 1.32 -0.98 0.33   
## Relig1 -1.40 1.32 -1.06 0.29   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.72 on 72 degrees of freedom  
## Multiple R-squared: 0.0264, Adjusted R-squared: -0.000633   
## F-statistic: 0.977 on 2 and 72 DF, p-value: 0.382

*What is the regression equation?*

*What does the intercept mean?*

*What do the coefficients for* CondC2 *and* Relig1 *mean?*

*What is the mean comfort level for non-religious people in Condition 1? For religious people in Condition 1? For non-religious people in Condition 2? For non-religious people in Condition 2?*

#### *How would you write up these results?*One continuous predictor, one categorical predictor

**Research question**: Does a subj's comfort with the idea of neuron replacement surgery depend his/her religion, and/or his/her enjoyment of scifi?

# Effects of Relig + EnjoyScifi on NeuronRepl  
r3c = lm(NeuronRepl ~ Relig + EnjoyScifi, data = xphil); summary(r3c)

##   
## Call:  
## lm(formula = NeuronRepl ~ Relig + EnjoyScifi, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -13.76 -4.04 1.82 4.22 9.56   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 4.262 1.044 4.08 0.00011 \*\*\*  
## Relig1 -0.957 1.299 -0.74 0.46380   
## EnjoyScifi 0.624 0.287 2.17 0.03294 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.58 on 72 degrees of freedom  
## Multiple R-squared: 0.0742, Adjusted R-squared: 0.0485   
## F-statistic: 2.88 on 2 and 72 DF, p-value: 0.0624

*What is the regression equation?*

*What does the intercept mean?*

*What do the coefficients for* Relig1 *and* EnjoyScifi *mean?*

*How would you write up these results?*

### Polynomial effects (a kind of "higher-order" term)

**Research question**: Does the effect of a subject's enjoyment of scifi on his/her comfort with the idea of neuron replacement surgery have a non-linear component?

# Effects of poly(EnjoyScifi, 2) on NeuronRepl  
r4a = lm(NeuronRepl ~ poly(EnjoyScifi, 2), data = xphil); summary(r4a)

##   
## Call:  
## lm(formula = NeuronRepl ~ poly(EnjoyScifi, 2), data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -14.43 -4.26 1.35 4.20 8.74   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 4.747 0.636 7.47 1.5e-10 \*\*\*  
## poly(EnjoyScifi, 2)1 12.753 5.504 2.32 0.023 \*   
## poly(EnjoyScifi, 2)2 8.733 5.504 1.59 0.117   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.5 on 72 degrees of freedom  
## Multiple R-squared: 0.0987, Adjusted R-squared: 0.0737   
## F-statistic: 3.94 on 2 and 72 DF, p-value: 0.0237

*What does the intercept mean?*

*What do the coefficients for* poly(EnjoyScif, 2)1 *and* poly(EnjoyScifi, 2)2 *mean?*

*How would you write up these results?*

### Interactions

#### Between continuous and categorical predictors

**Research question**: Does the (linear) effect of a subject's enjoyment of scifi on his/her comfort with the idea of neuron replacement surgery depend on...

...the subject's condition?

r5a = lm(NeuronRepl ~ EnjoyScifi \* Cond, data = xphil); summary(r5a)

##   
## Call:  
## lm(formula = NeuronRepl ~ EnjoyScifi \* Cond, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -13.43 -3.43 1.55 4.07 8.76   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 4.807 1.151 4.18 8.3e-05 \*\*\*  
## EnjoyScifi 0.323 0.429 0.75 0.45   
## CondC2 -1.914 1.566 -1.22 0.23   
## EnjoyScifi:CondC2 0.561 0.574 0.98 0.33   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.58 on 71 degrees of freedom  
## Multiple R-squared: 0.0879, Adjusted R-squared: 0.0494   
## F-statistic: 2.28 on 3 and 71 DF, p-value: 0.0865

*What does the intercept mean?*

*What do the coefficients for* EnjoyScifi*,* CondC2*, and* EnjoyScifi:CondC2 *mean?*

*How would you write up these results?*

... the subject's religion?

r5b = lm(NeuronRepl ~ EnjoyScifi \* Relig, data = xphil); summary(r5b)

##   
## Call:  
## lm(formula = NeuronRepl ~ EnjoyScifi \* Relig, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -14.87 -3.82 1.26 4.20 7.99   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 3.340 1.198 2.79 0.0068 \*\*  
## EnjoyScifi 1.132 0.437 2.59 0.0117 \*   
## Relig1 0.427 1.574 0.27 0.7867   
## EnjoyScifi:Relig1 -0.879 0.575 -1.53 0.1309   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.53 on 71 degrees of freedom  
## Multiple R-squared: 0.104, Adjusted R-squared: 0.0658   
## F-statistic: 2.74 on 3 and 71 DF, p-value: 0.0498

*What does the intercept mean?*

*What do the coefficients for* EnjoyScifi*,* Relig1*, and* EnjoyScifi:Relig1 *mean?*

*If the last term were significant (e.g., p = 0.001 instead of p = 0.131), which religious group would you conclude is more strongly affected by their enjoyment of science fiction?*

*How would you write up these results?*

What about the *non-linear* effect of the subject's enjoyment of scifi? Does it vary by religion?

r5c = lm(NeuronRepl ~ poly(EnjoyScifi,2) \* Relig, data = xphil); summary(r5c)

##   
## Call:  
## lm(formula = NeuronRepl ~ poly(EnjoyScifi, 2) \* Relig, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -14.61 -3.75 1.32 4.23 9.23   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 5.053 0.891 5.67 3e-07 \*\*\*  
## poly(EnjoyScifi, 2)1 22.571 8.516 2.65 0.01 \*\*   
## poly(EnjoyScifi, 2)2 -2.270 8.273 -0.27 0.78   
## Relig1 -0.993 1.265 -0.79 0.43   
## poly(EnjoyScifi, 2)1:Relig1 -15.914 11.167 -1.43 0.16   
## poly(EnjoyScifi, 2)2:Relig1 18.370 11.037 1.66 0.10   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.42 on 69 degrees of freedom  
## Multiple R-squared: 0.163, Adjusted R-squared: 0.103   
## F-statistic: 2.7 on 5 and 69 DF, p-value: 0.0277

*What does the intercept mean?*

*What do all the other coefficients mean?*

*Consider the last term to be marginally significant: What is different about the relationship between enjoyment of science fiction and comfort with the neuron replacement surgery for Judeo-Christian vs. non-religious people?*

*How would you write up these results?*

#### Among categorical predictors

**Research question**: Does the effect of a subject's religion on his/her comfort with neuron replacement surgery depend on his/her experimental condition?

r6 = lm(NeuronRepl ~ Cond \* Relig, data = xphil); summary(r6)

##   
## Call:  
## lm(formula = NeuronRepl ~ Cond \* Relig, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -12.59 -3.99 1.25 4.59 8.35   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 7.22 1.33 5.42 7.6e-07 \*\*\*  
## CondC2 -3.47 1.84 -1.89 0.063 .   
## Relig1 -3.57 1.84 -1.95 0.056 .   
## CondC2:Relig1 4.41 2.62 1.69 0.096 .   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.65 on 71 degrees of freedom  
## Multiple R-squared: 0.0639, Adjusted R-squared: 0.0243   
## F-statistic: 1.62 on 3 and 71 DF, p-value: 0.193

*What does the intercept mean?*

*What do all the other coefficients mean?*

*Consider the last term to be marginally significant: What is different about the effect of condition on comfort with the neuron replacement surgery for Judeo-Christian vs. non-religious people?*

*How would you write up these results?*

#### Among continuous predictors

**Research question**: Does the effect of a subject's enjoyment of scifi on his/her comfort with the idea of neuron replacement surgery depend on how often s/he thinks about these kinds of questions?

r7 = lm(NeuronRepl ~ EnjoyScifi \* ThinkOften, data = xphil); summary(r7)

##   
## Call:  
## lm(formula = NeuronRepl ~ EnjoyScifi \* ThinkOften, data = xphil)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -13.79 -3.85 1.31 4.09 8.31   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 2.99346 1.15101 2.60 0.011 \*  
## EnjoyScifi 0.00551 0.42409 0.01 0.990   
## ThinkOften 0.10962 0.72421 0.15 0.880   
## EnjoyScifi:ThinkOften 0.28688 0.21370 1.34 0.184   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 5.48 on 71 degrees of freedom  
## Multiple R-squared: 0.12, Adjusted R-squared: 0.0824   
## F-statistic: 3.21 on 3 and 71 DF, p-value: 0.0279

# Note how the "main effects" disappear!

*What does the intercept mean?*

*What do all the other coefficients mean?*

*How would you write up these results?*