Linear Models

and Other Fun Times in R

What is a Linear Mixed Effects Model?

- Models prediction of the effects of independent variables on outcome variables

- Takes into account random variation

- e.g. differences between participants, or stimulus items

Why do I need to use a LMER?

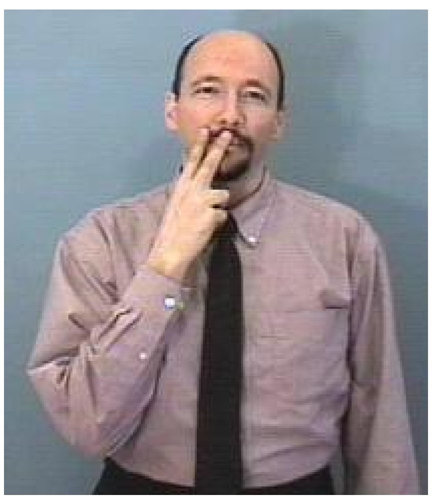
- Participants give multiple responses (that is, you have multiple measures per participant)

- Individual participants might respond in the same general way, but to different extents

  e.g. some participants might just be 'better' at a task

Example: ASL reaction times

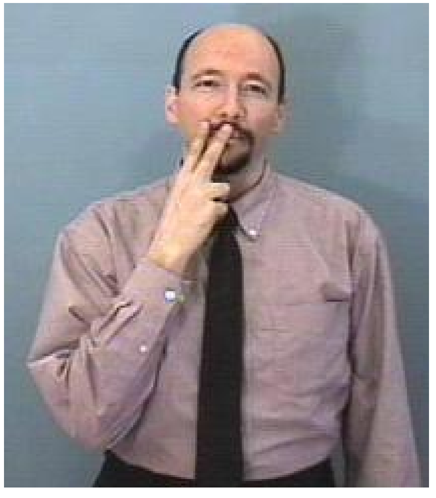
Imagine a study that takes signs from American sign language and asks participants to match them to their English equivalents



To smoke

Example: ASL reaction times

We want to know if how iconic a sign is rated affects the reaction time of participants to link it to a label



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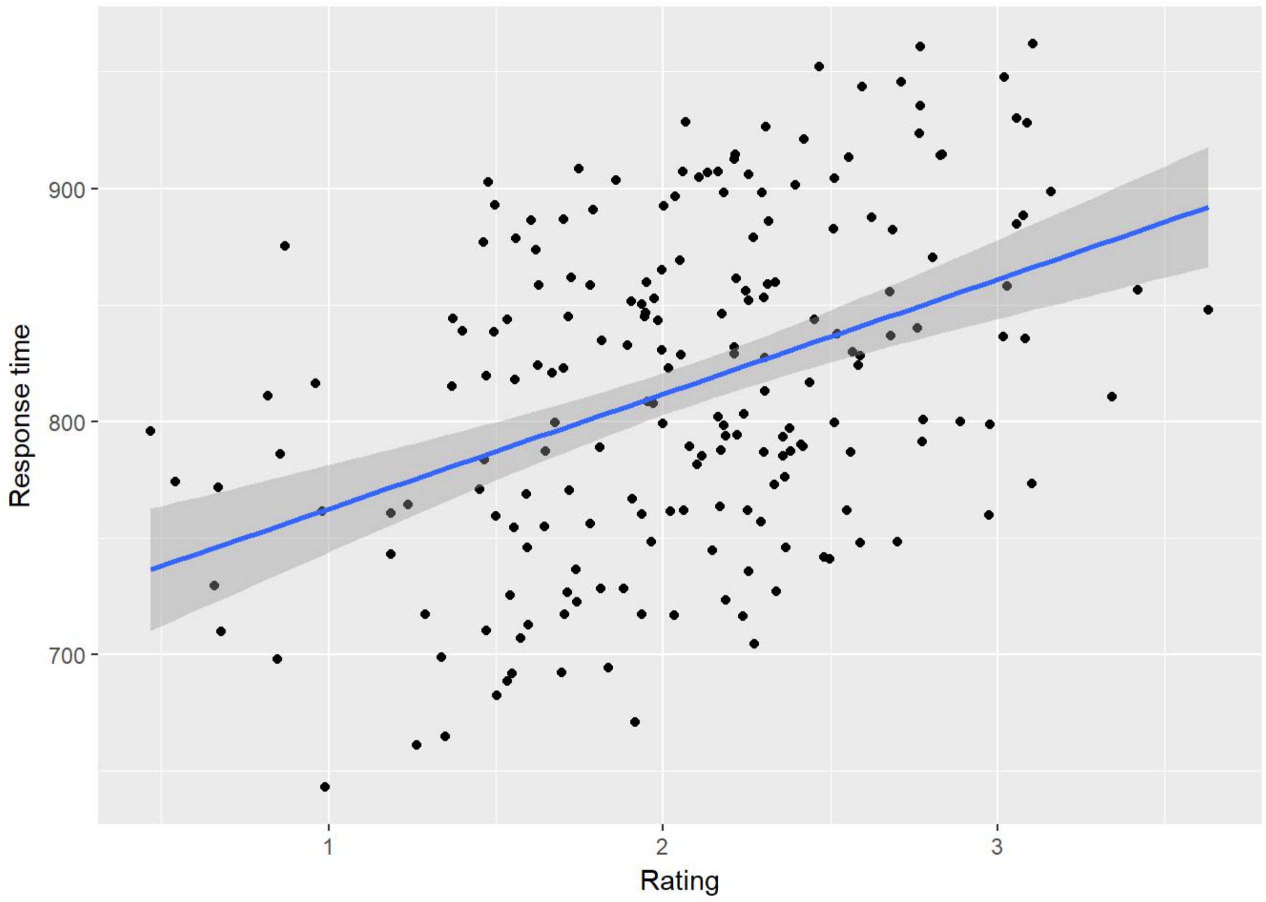
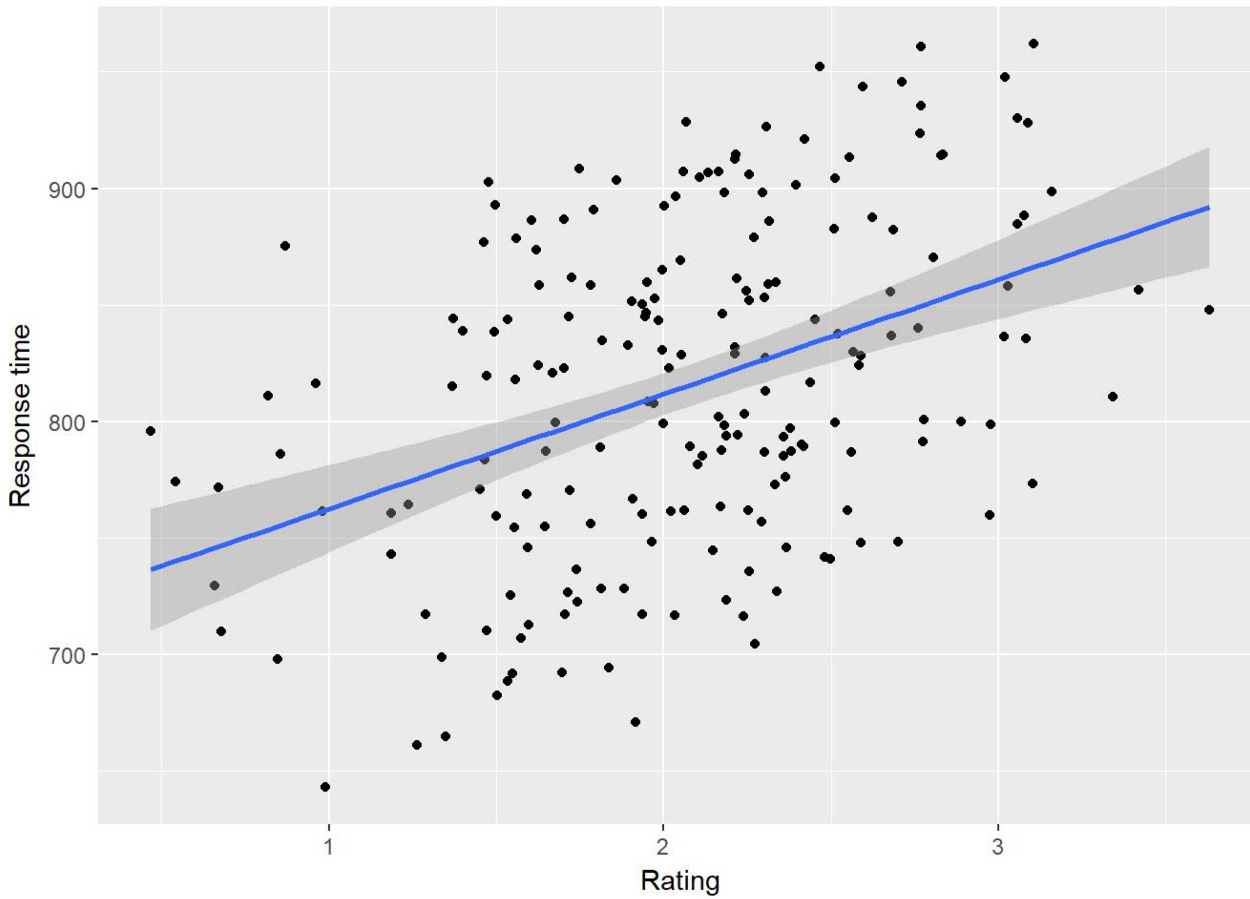


Example: ASL reaction times



Baus, Carreiras and Emmorey (2012)

Example: ASL reaction times

```
RT_model = lm(RT ~ Rating)
```

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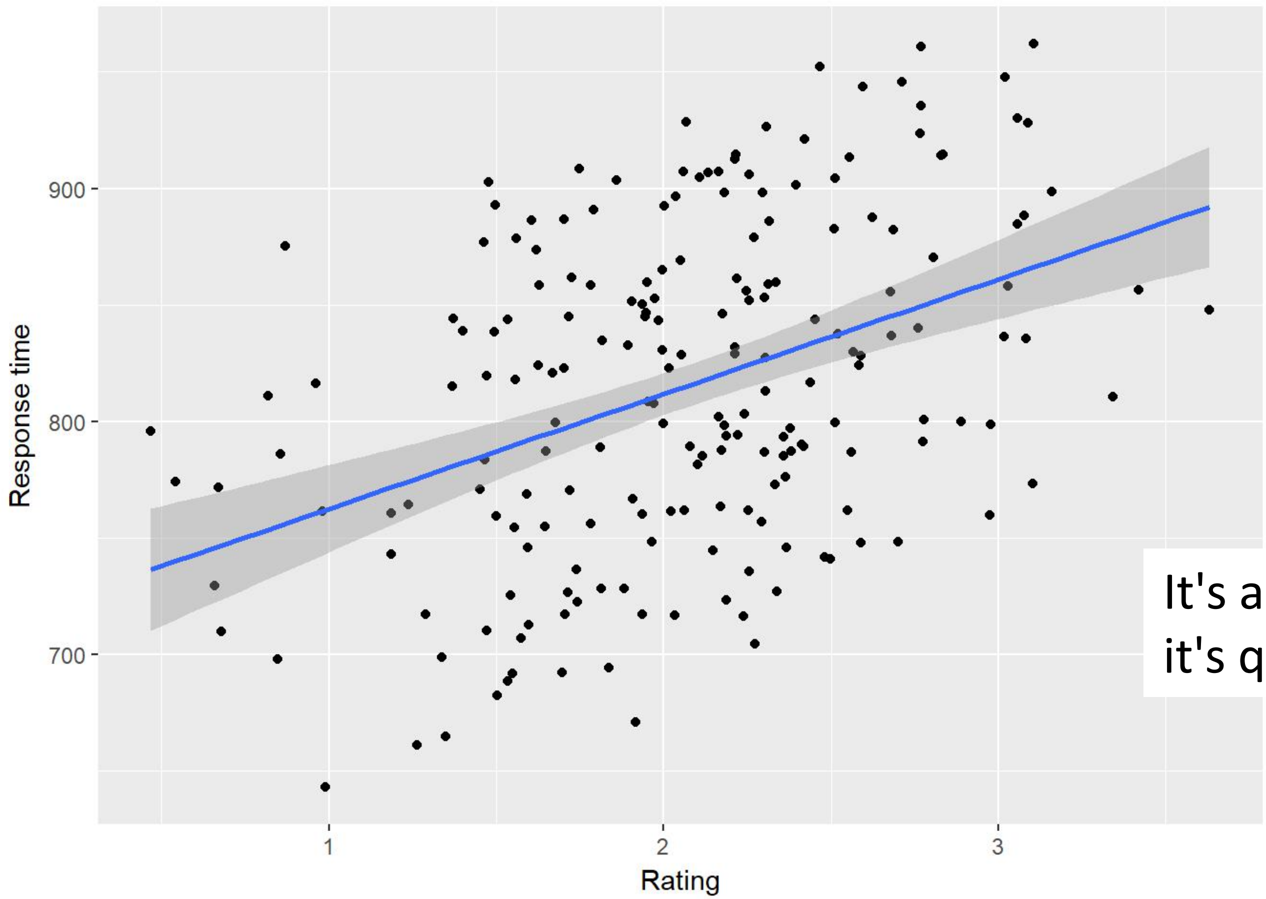
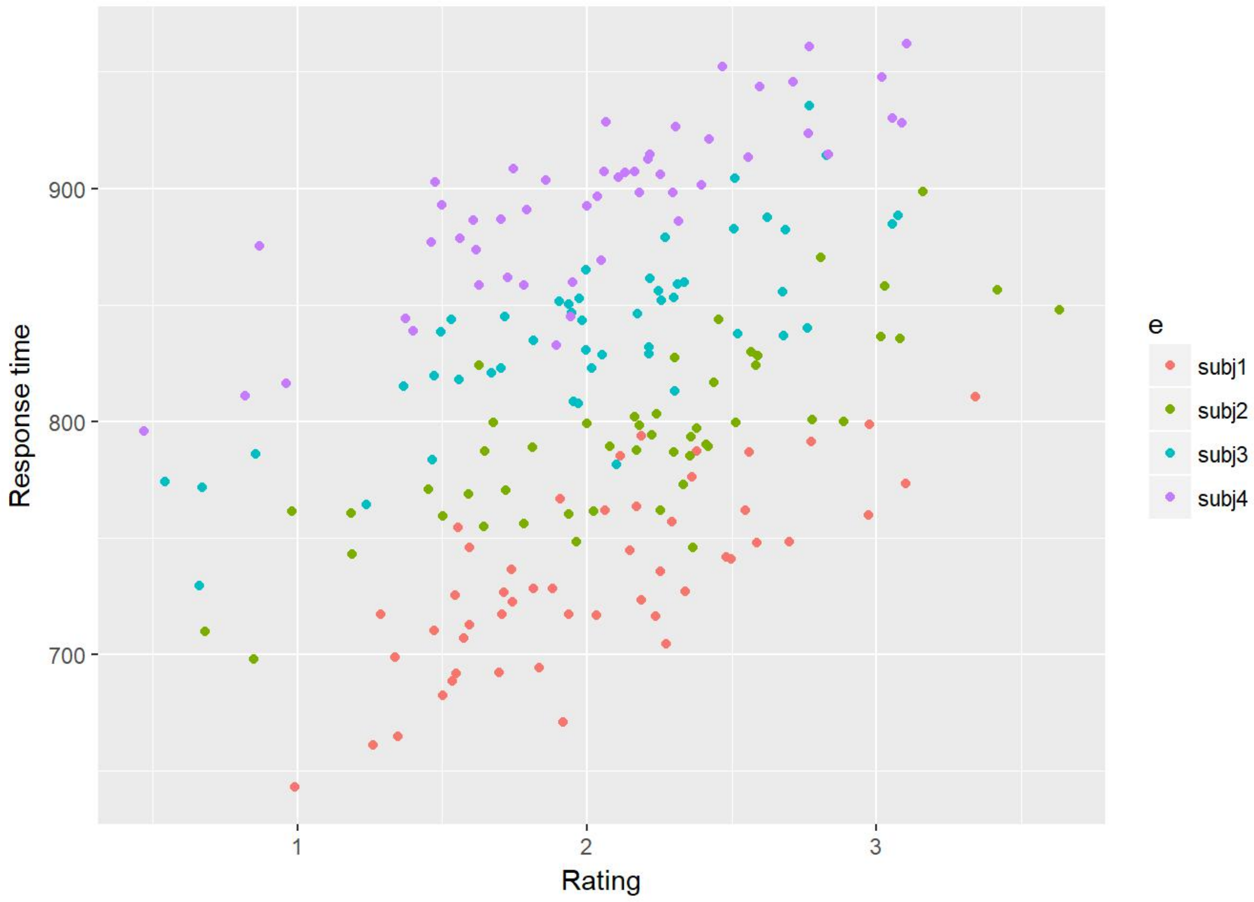


It's alright, but
it's quite noisy

Example: ASL reaction times



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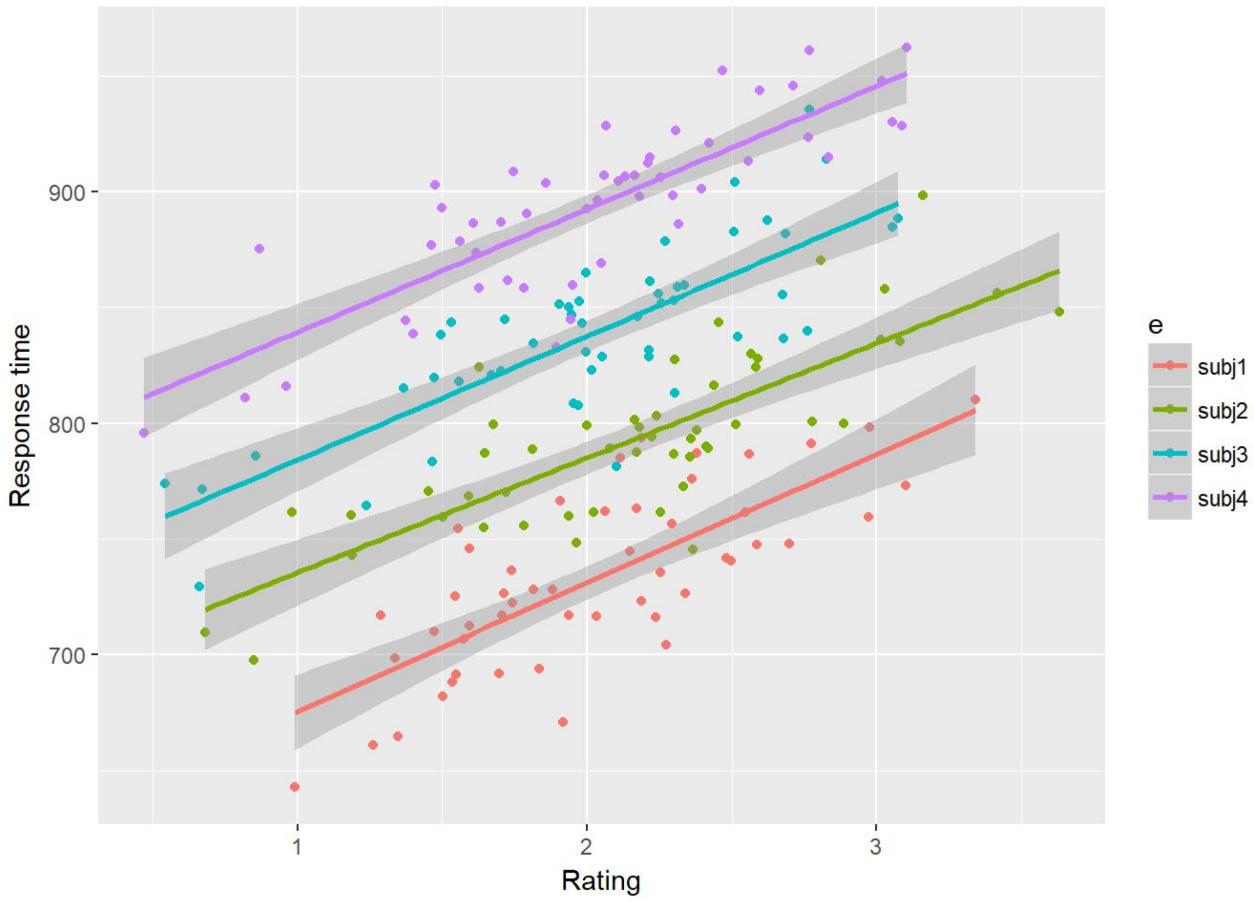

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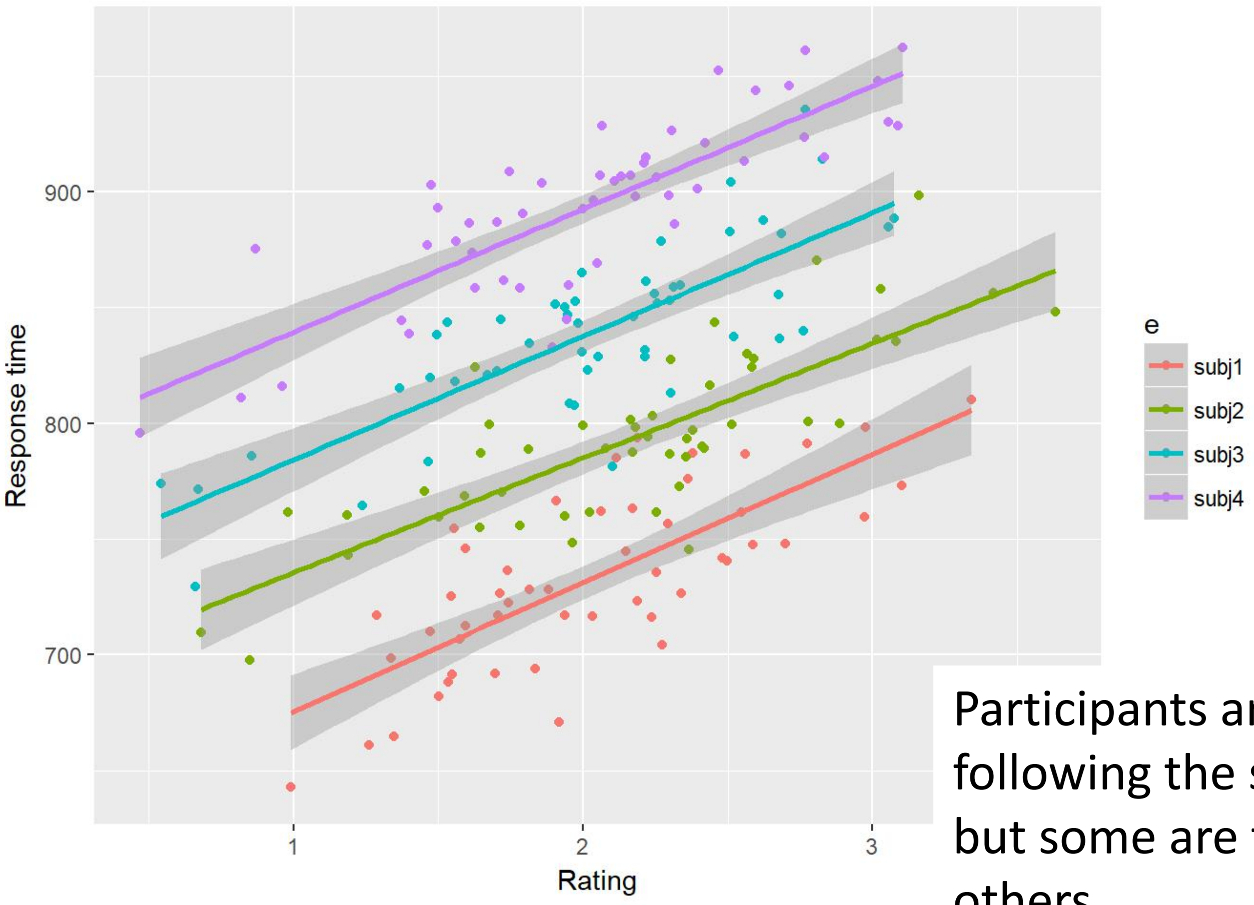


Participants are following the same trend, but some are faster than others

Example: ASL reaction times

RT_model_mixed = lmer(RT ~ Rating + (1|Participant))

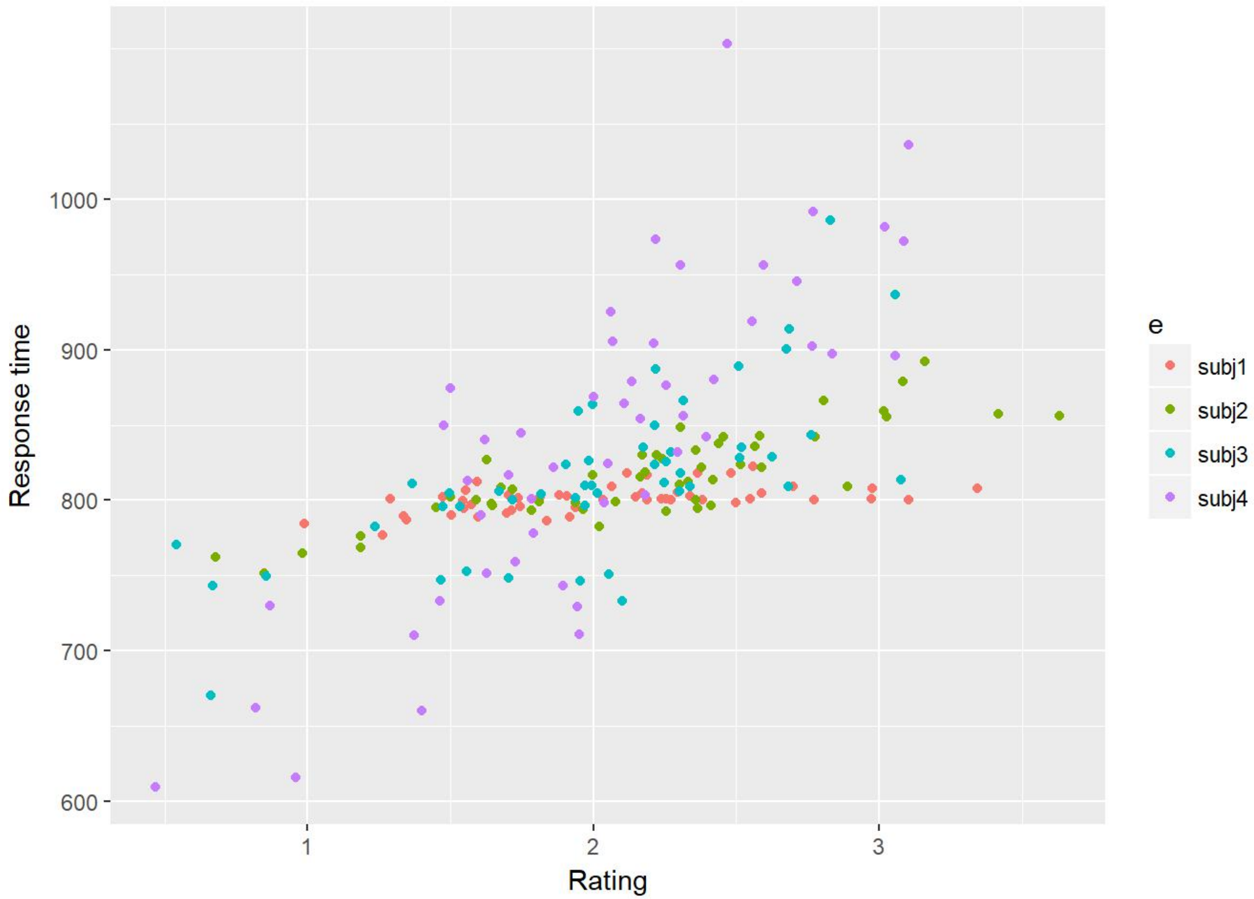
This is a random intercept

Example: ASL reaction times

RT_model_mixed = lmer(RT ~ Rating + (1|Participant))

This tells our model that some of our participants might generally be faster/slower than others

Example: ASL reaction times



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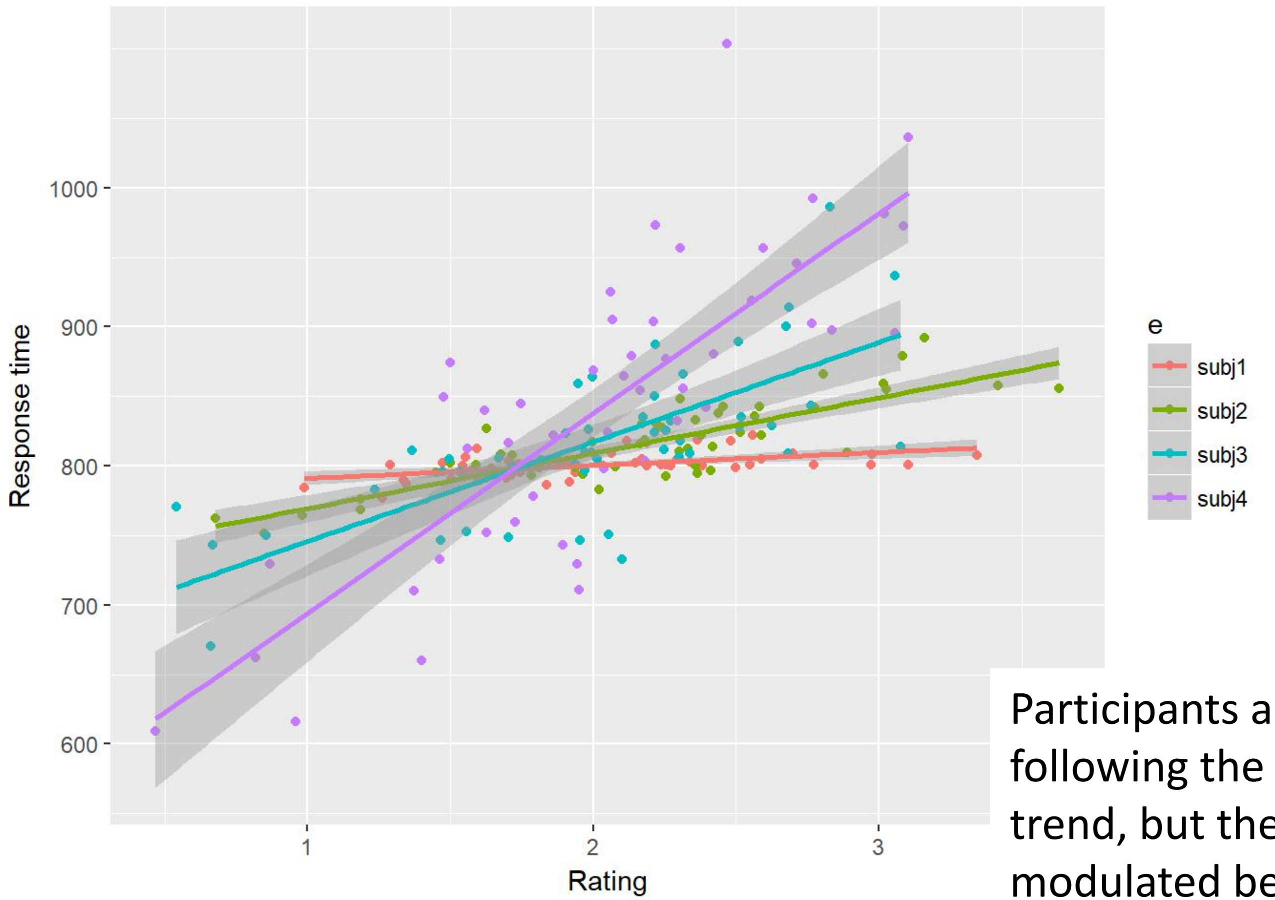

Participants are following the same trend, but the effect is modulated between participants

Example: ASL reaction times

RT_model_mixed = lmer(RT ~ Rating + (1+Rating|Participant))

The 1 + item is a random slope!

Example: ASL reaction times

```
RT_model_mixed = lmer(RT ~ Rating + (1+Rating|Participant))
```

This tells us that different participants might behave differently for high iconic signs vs low iconic signs

Example: ASL reaction times

We can compare 2 models to check which is a better fit to the data.

Example: ASL reaction times

Model 1 - lm (not mixed effects)

```
## Call:
## lm(formula = RT ~ Rating, data = data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -16.6139  -2.4879  -0.4224   2.4550  17.9977
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   1.0284     0.3542   2.903  0.00411 **
## Rating        1.3336     0.1192  11.190  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
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```

Model 2 -lmer (mixed effects)

```
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   0.9118     0.4452   2.048
## Rating        1.3627     0.5557   2.452
##
```

Example: ASL reaction times

Comparing 2 models

```
anova(model2, model1)
```

```
## Data: data
## Models:
## model1: RT ~ Rating
## model2: RT ~ Rating + (1 + Rating | participant)
##        Df    AIC    BIC  logLik deviance  Chisq Chi Df Pr(>Chisq)
## model1  3 1216.0 1225.9 -605.00   1210.0
## model2  6 1107.5 1127.3 -547.77   1095.5 114.46      3  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The model with random effects fits the data better than the model without!

To think about:
what is a fixed effect?
what is a random effect?

Fixed v. Random Effects

Fixed

- Predictable, systematic
- Exhausts the population
- Constant across individuals
- Conditions set by researcher
- Continuous or categorical

Random

- Idiosyncratic and unpredictable
- A random sample of possible levels
- Varies between individuals
- Researcher interested in underlying population
- Categorical

Fixed effects

You can test multiple fixed effects

e.g. RT ~ Rating + Condition

Fixed effects

You can test multiple fixed effects

e.g. RT ~ Rating + Condition

And their interaction

e.g RT ~ Rating * Condition

Random effects

You can have random intercepts without random slopes

e.g. (1|Participant)

The intercepts and slopes you use depend on your experimental design - i.e. what measures are within or between subjects

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Data types and model types

The example I just showed has continuous numerical output, so we used a **linear** model.

You can run mixed effects models with different types of data:

for binary data --> logistic/logit model

for count data --> poisson model

Let’s look at our data

Recall: The Variables

What do you think might be our fixed effects?

What do you think might be our random effects?

Further reading and practice

Cunnings, I. (2012). An overview of mixed-effects statistical models for second language researchers. Second Language Research, 28, 369–382.

Winter, B., & Wieling, M. (2016). How to analyze linguistic change using mixed models, Growth Curve Analysis and Generalized Additive Modeling. Journal of Language Evolution, 1(1), 7-18. **+ additional tutorial**

Coxe, S., West, S. G., & Aiken, L. S. (2009). The Analysis of Count Data: A Gentle Introduction to Poisson Regression and Its Alternatives. Journal of Personality Assessment, 91(2), 121–136.

Bodo Winter's tutorials:

http://www.bodowinter.com/tutorials.html