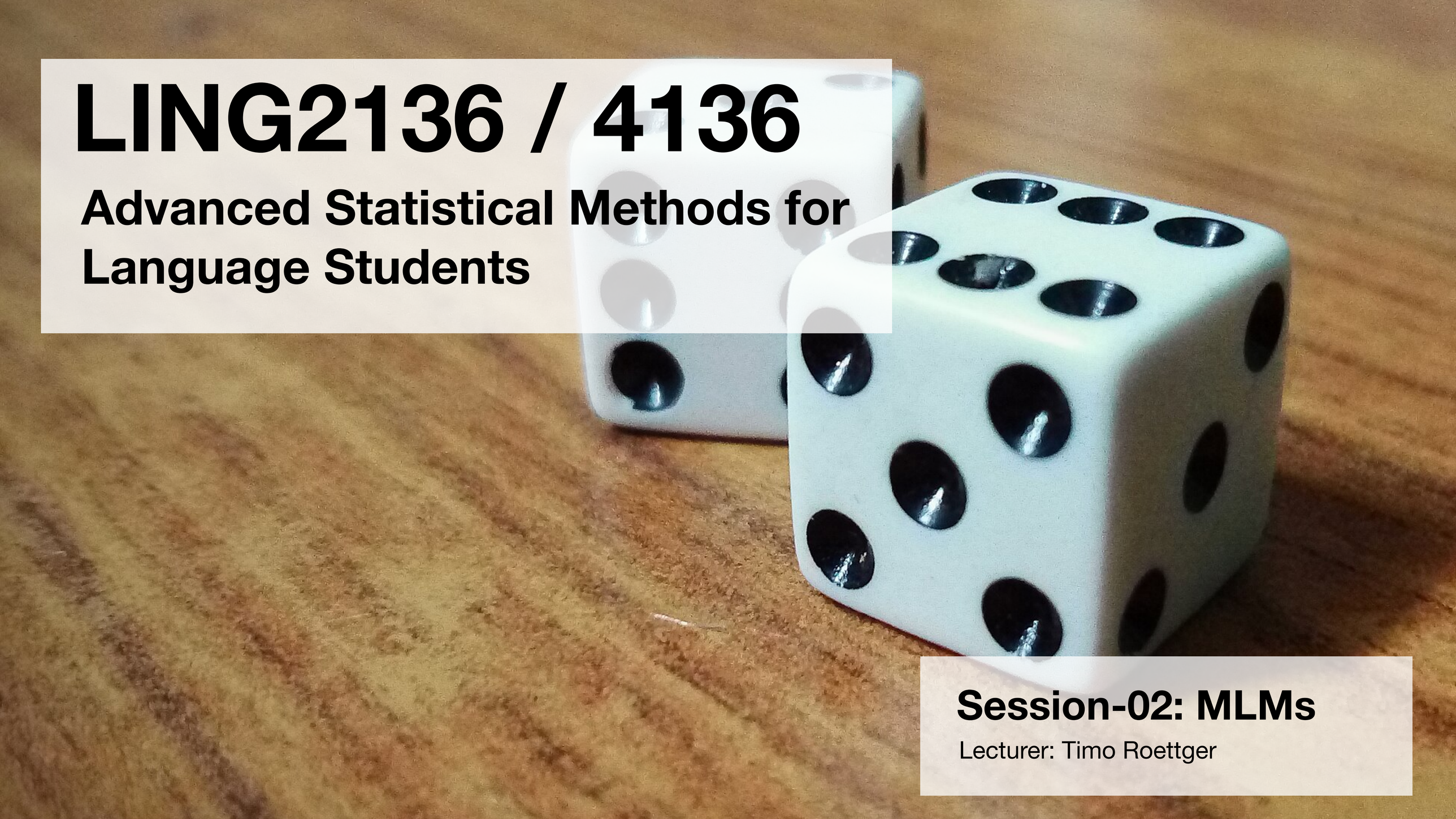


LING2136 / 4136

Advanced Statistical Methods for Language Students

Session-02: MLMs

Lecturer: Timo Roettger

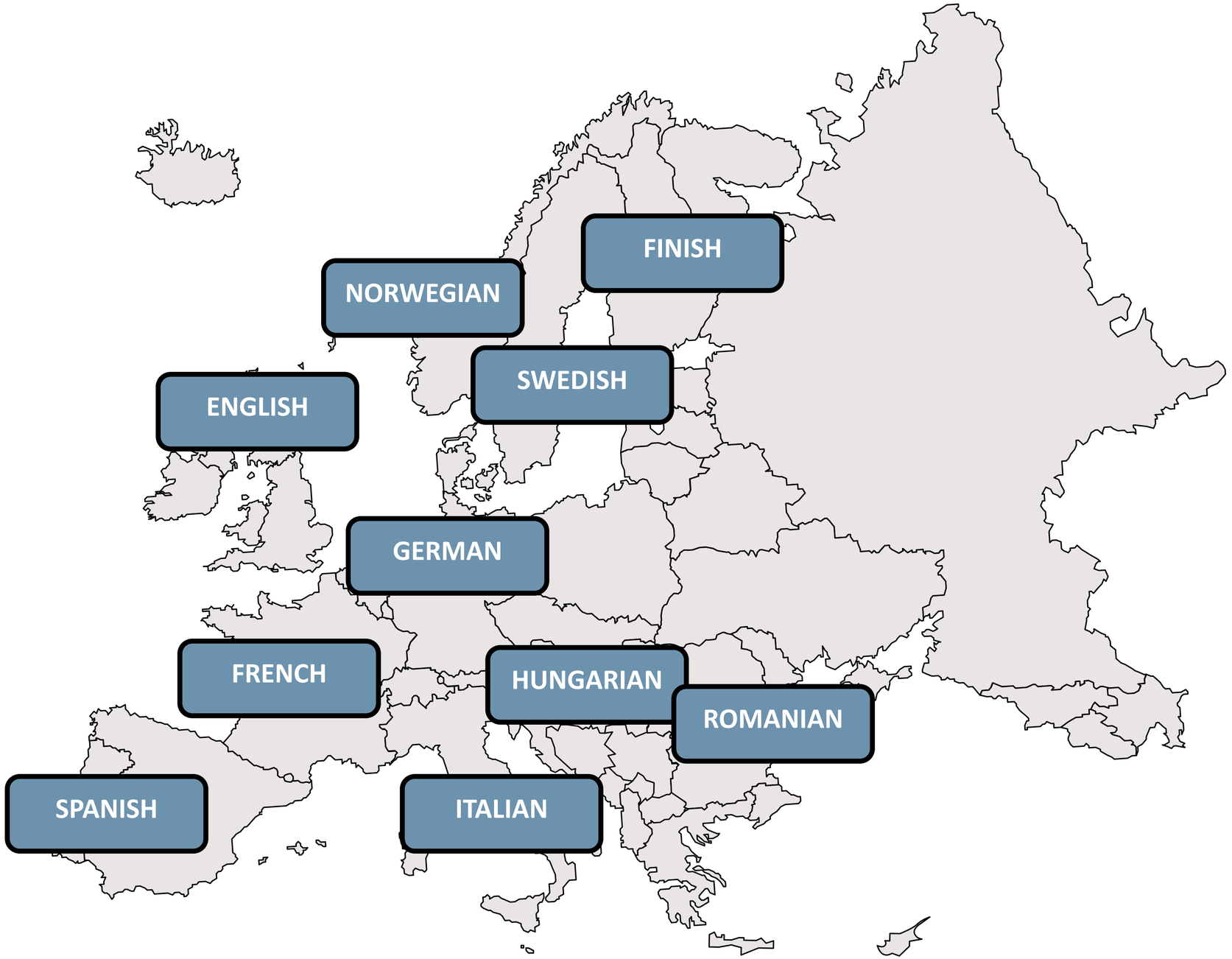
Multilevel linear models

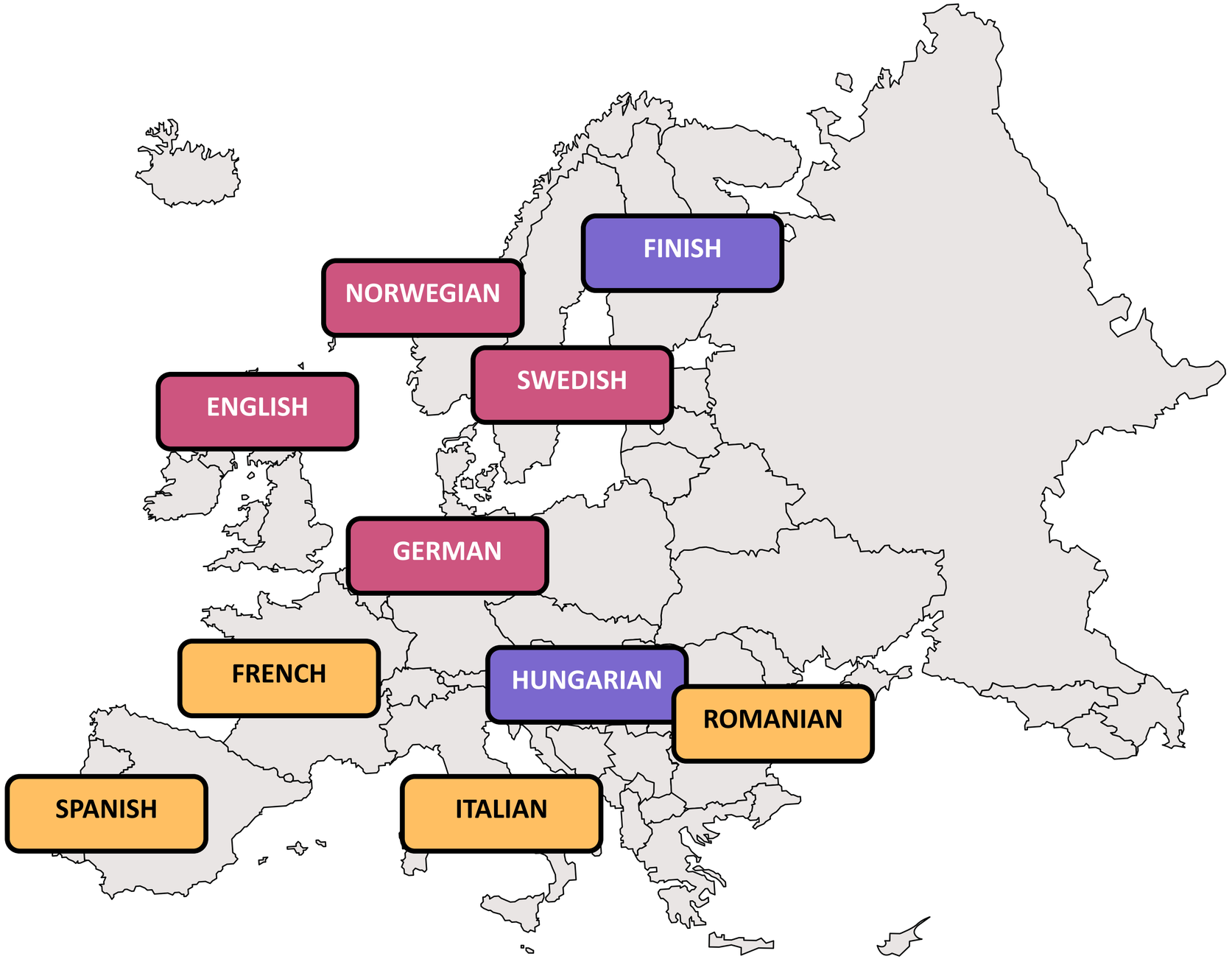
aka hierarchical linear model

aka linear mixed effects models

EXAMPLE: TENSE AND SAVINGS BEHAVIOR

Chen (2013) “The Effect of Language on Economic Behavior: Evidence from Savings Rates, Health Behaviors, and Retirement Assets.”


FINISH
NORWEGIAN
SWEDISH
ENGLISH
GERMAN
FRENCH
HUNGARIAN
ROMANIAN
SPANISH
ITALIAN


FINISH
NORWEGIAN
SWEDISH
ENGLISH
GERMAN
FRENCH
HUNGARIAN
ROMANIAN
SPANISH
ITALIAN

Subject	Item	Condition
S1	1	Test
S1	1	Control
S1	2	Test
S1	2	Control
S2	1	Test
S2	1	Control
S2	2	Test
S2	2	Control

Multilevel perspective & lme4 syntax

intercept slope

$$y_i = b_0 + b_1 * x_i$$

```
lm(y ~ 1 + x)
```

Multilevel perspective & lme4 syntax

intercept slope

$$y_{ij} = b_{0j} + b_1 * x_{ij}$$

```
lmer(y ~ 1 + x + (1|group))
```

random intercepts

Multilevel perspective & lme4 syntax

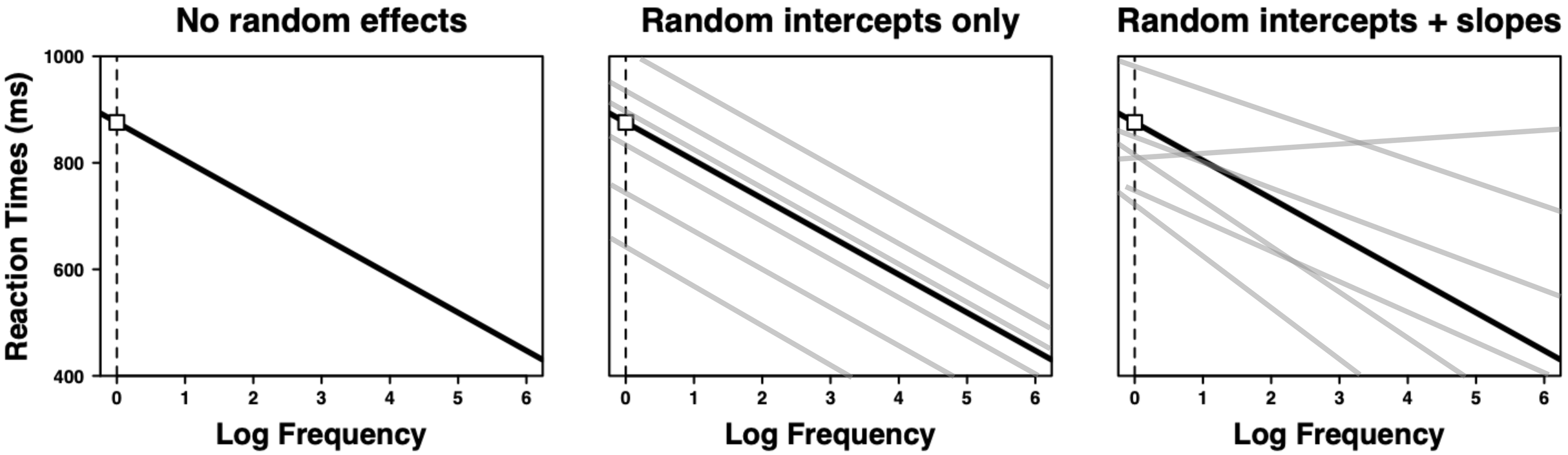
intercept slope

$$y_{ij} = b_{0j} + b_{1j} * x_{ij}$$

```
lmer(y ~ 1 + x + (1 + x|group))
```

random slope

random intercepts


No random effects
Random intercepts only
Random intercepts + slopes
Reaction Times (ms)
1000
800
600
400
0
1
2
3
4
5
6
Log Frequency

Multilevel perspective & lme4 syntax

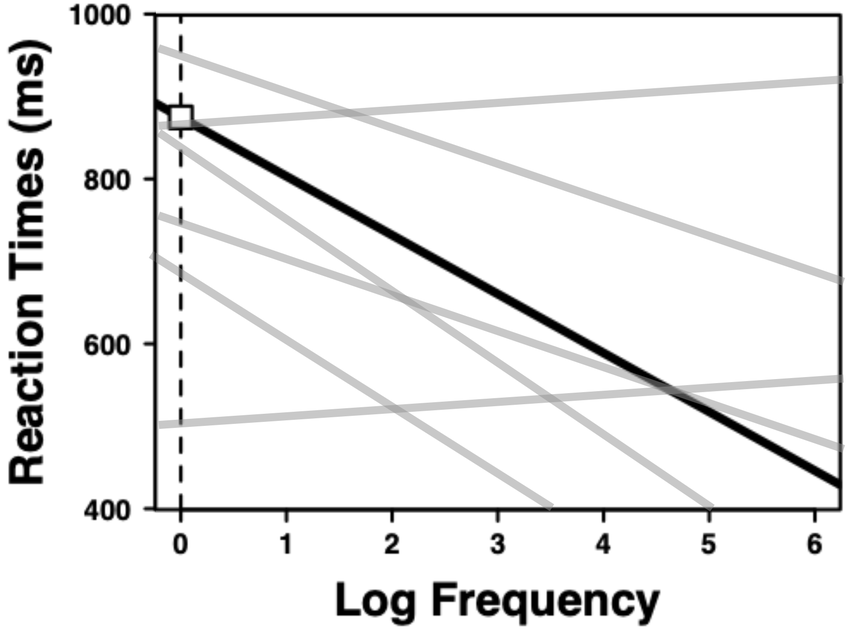
```
lmer(y ~ 1 + x + (1 + x|group))
```

intercepts & slopes are correlated

```
lmer(y ~ 1 + x + (0 + x|group))
```

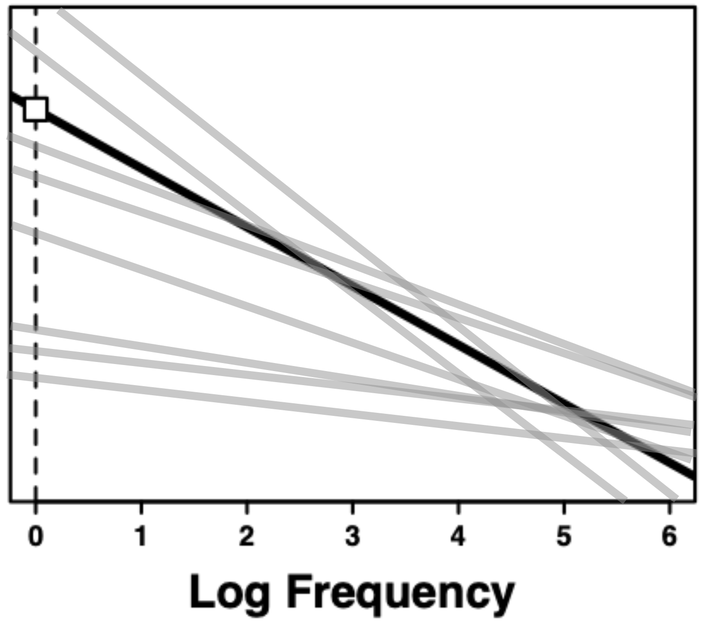
intercepts & slopes are NOT correlated

intercepts & slopes are NOT correlated

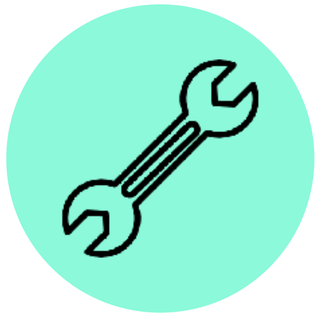


Slope variation between groups does not depend on their intercepts

intercepts & slopes are correlated



Slope variation between groups depends on their intercepts, e.g. higher intercepts have steeper slopes



Simulation

“Fixed” vs. “Random” effects

(1) Effects are fixed if they are **interesting in themselves** or random if there is interest in the underlying population. Searle et al. (1992)

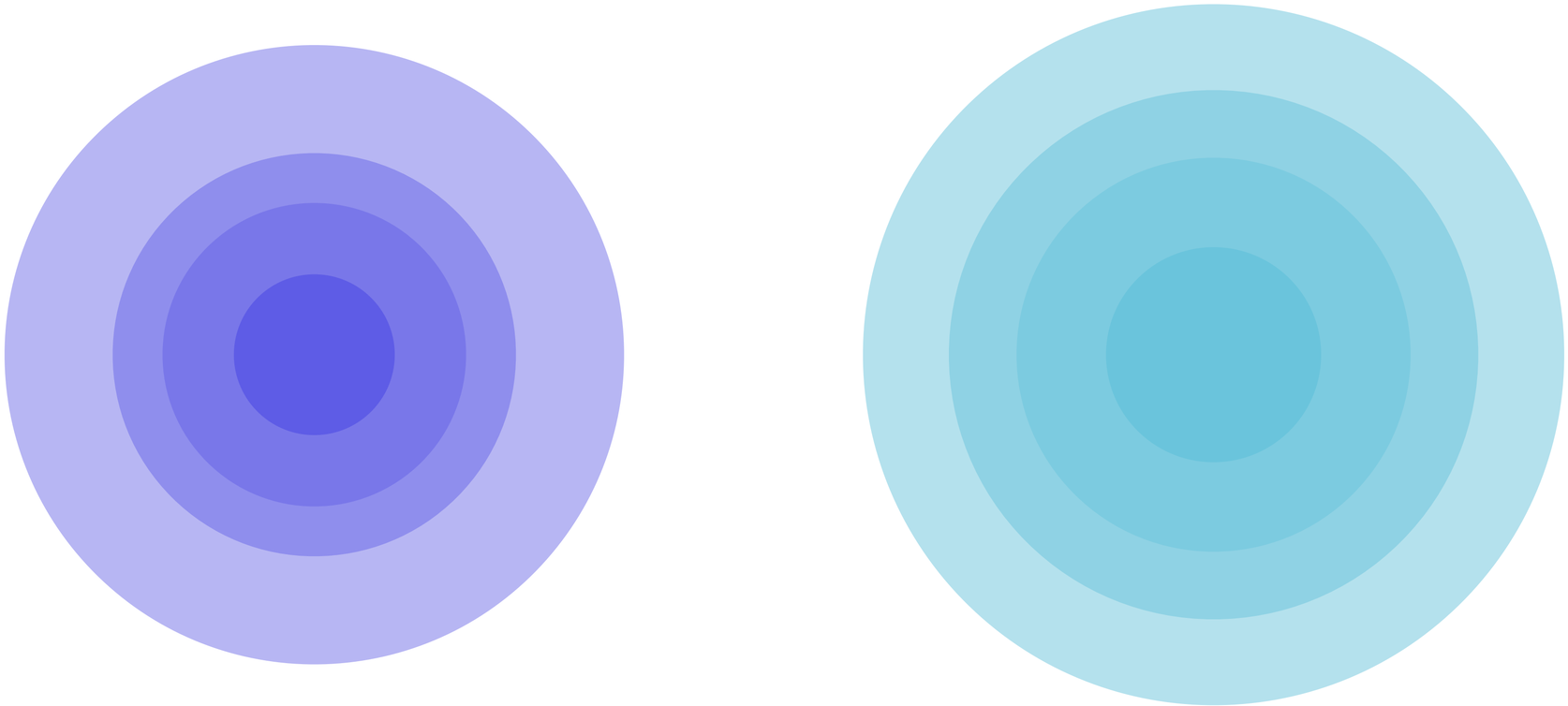
(2) “When a sample **exhausts the population**, the corresponding variable is *fixed*; when the sample is **a small (i.e., negligible) part of the population** the corresponding variable is *random*.” Green & Tukey (1960)

—> If you want to **generalize beyond a sample** of those levels, you treat it as random.

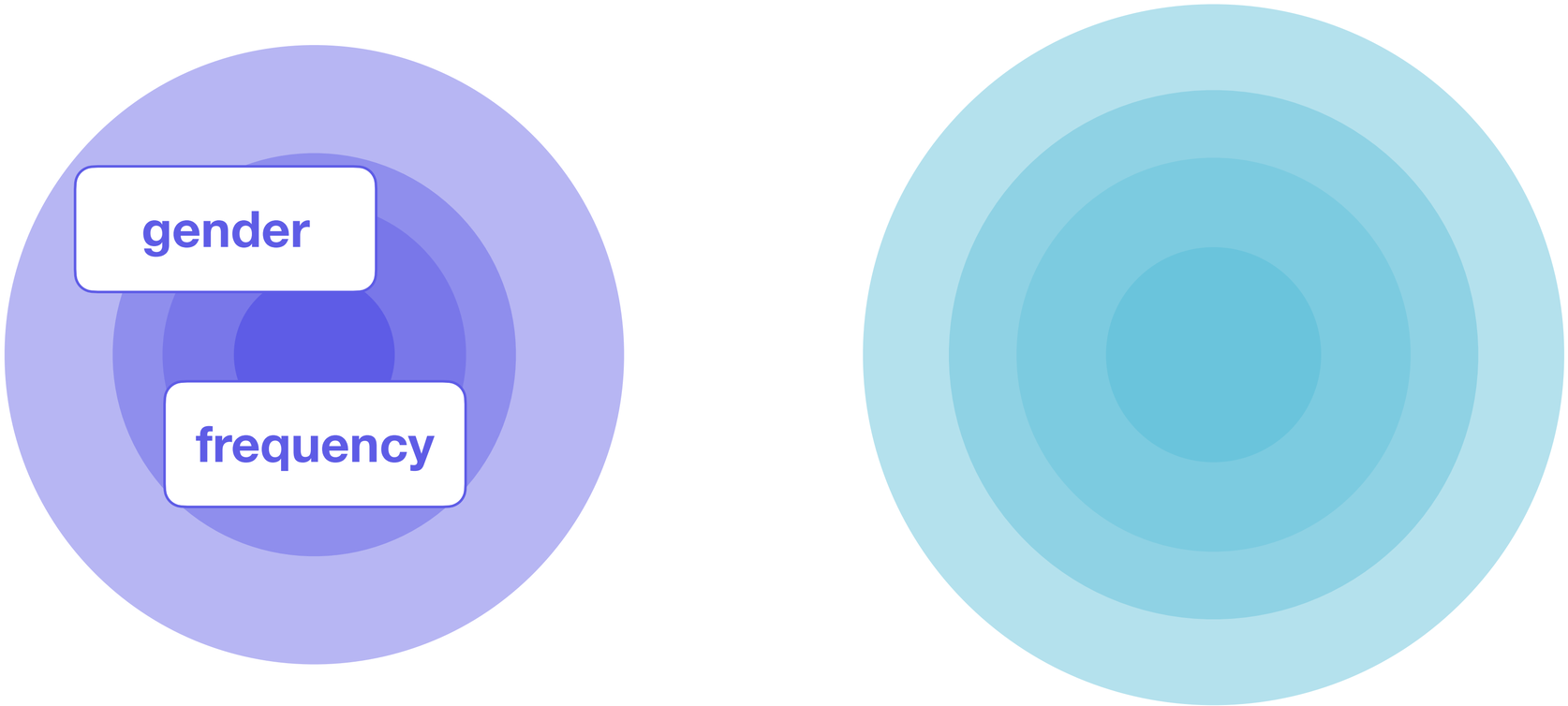
Green, B. F., and Tukey, J. W. (1960). Complex analyses of variance: general problems. *Psychometrika*

Searle, S. R., Casella, G., and McCulloch, C. E. (1992). Variance Components. New York: Wiley.

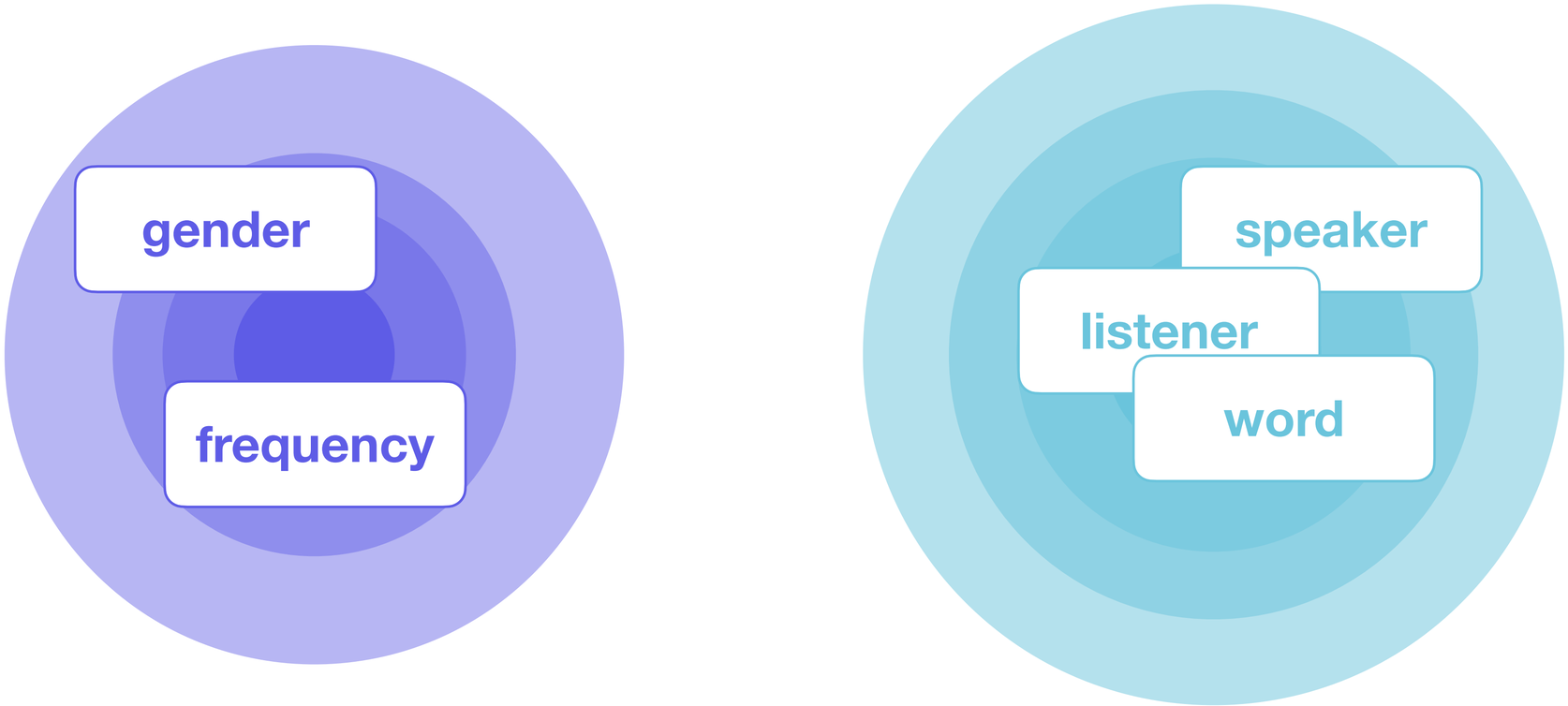
“Fixed” vs. “Random” effects



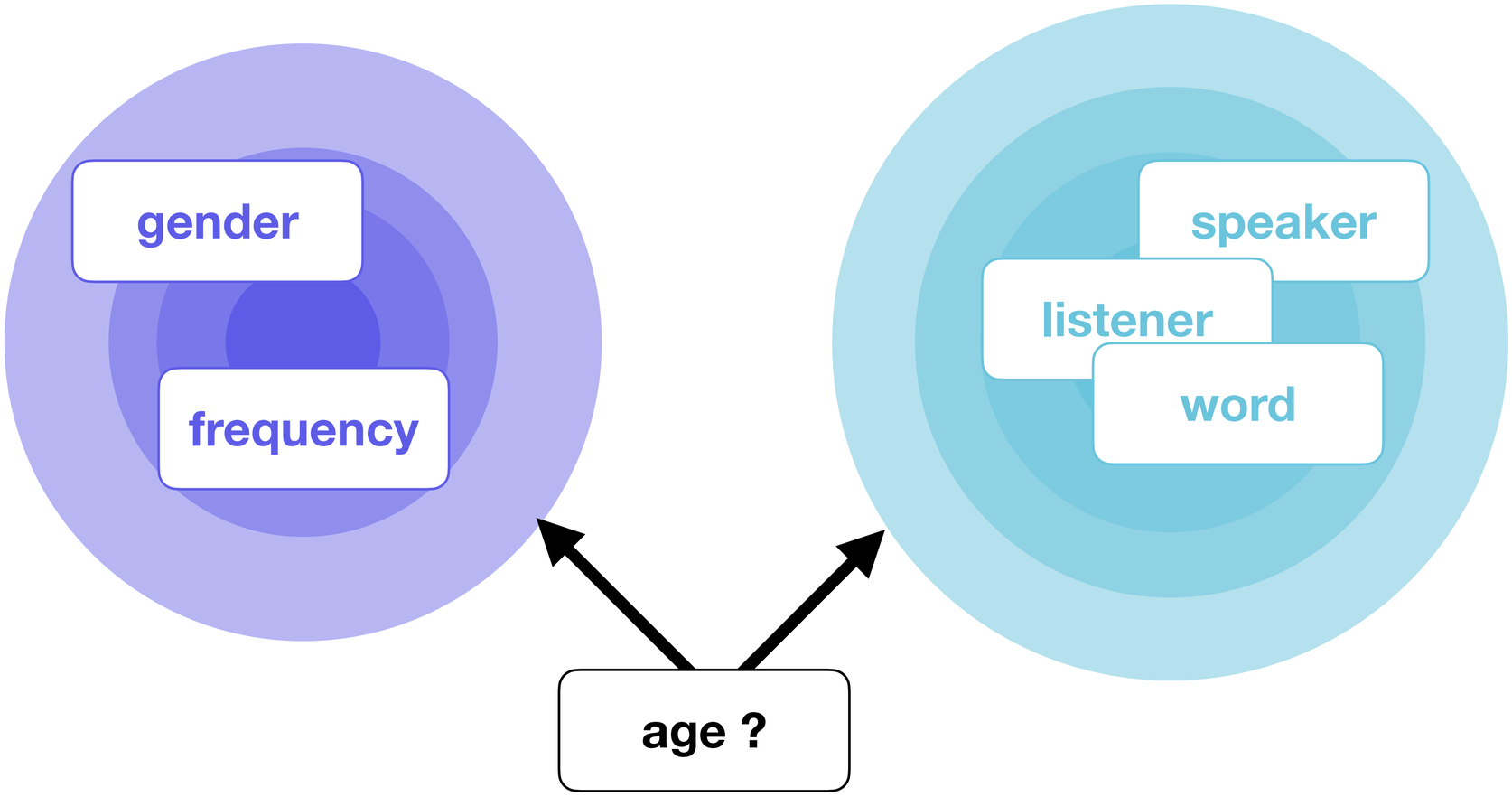
“Fixed” vs. “Random” effects



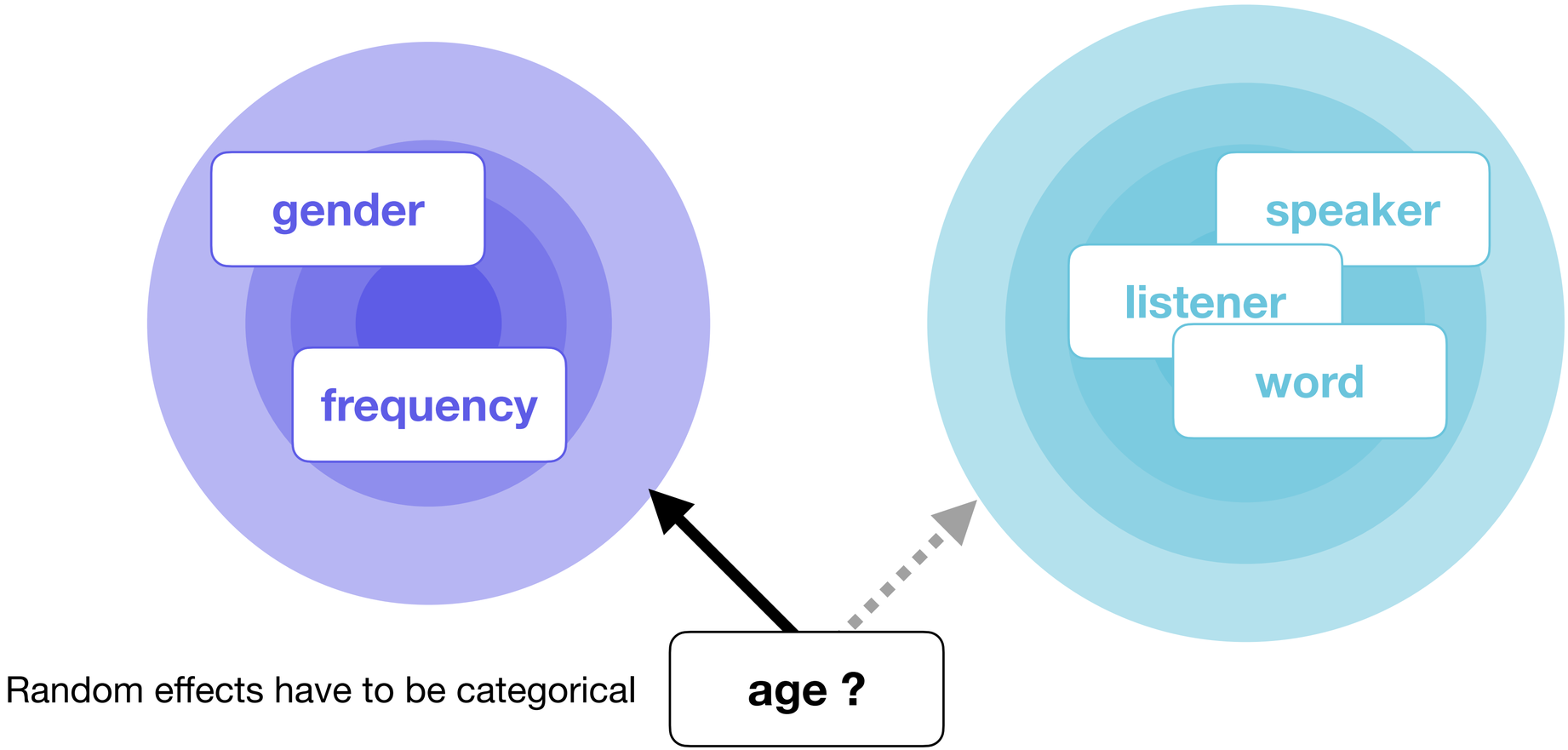
“Fixed” vs. “Random” effects



“Fixed” vs. “Random” effects

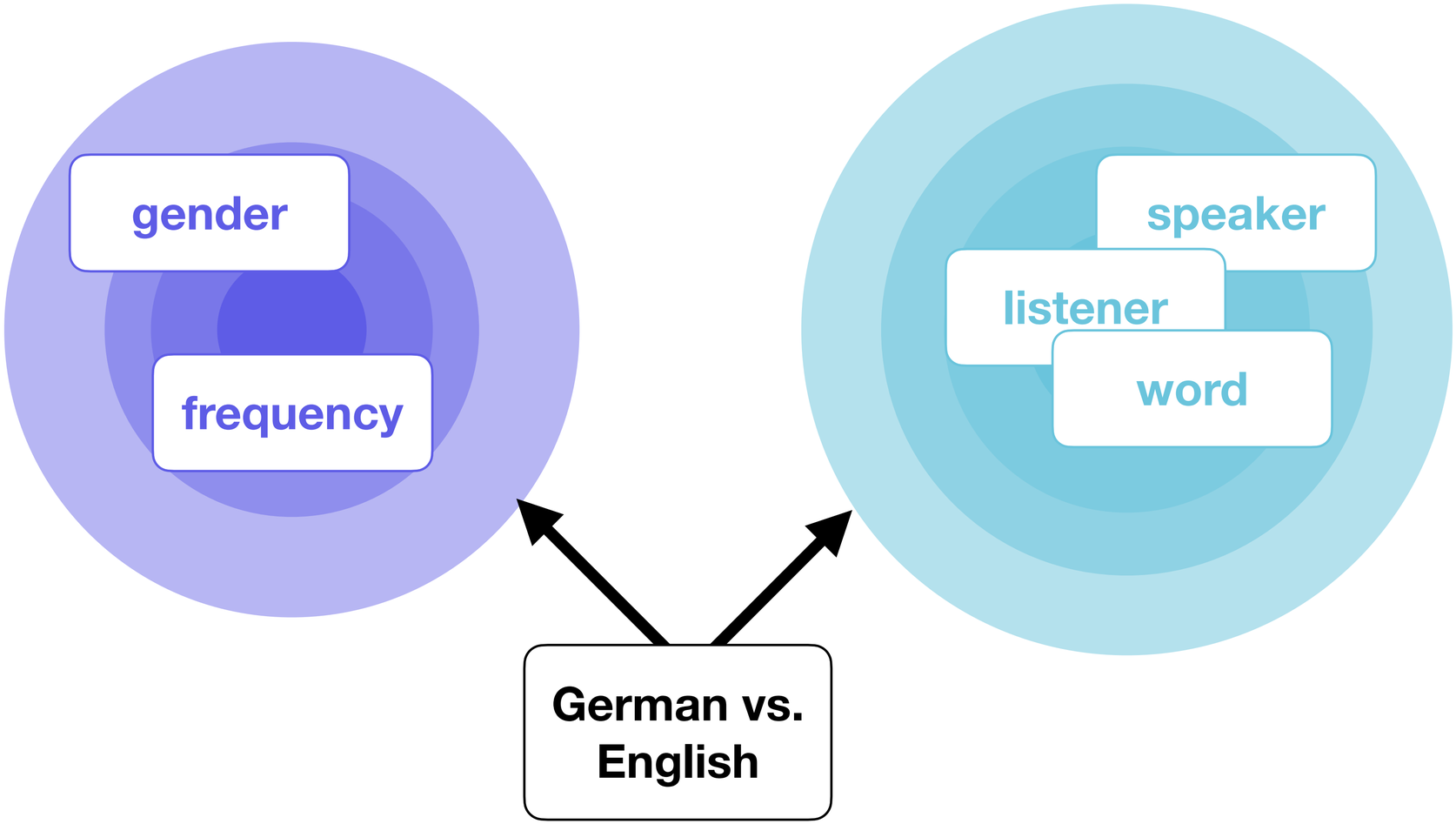


“Fixed” vs. “Random” effects

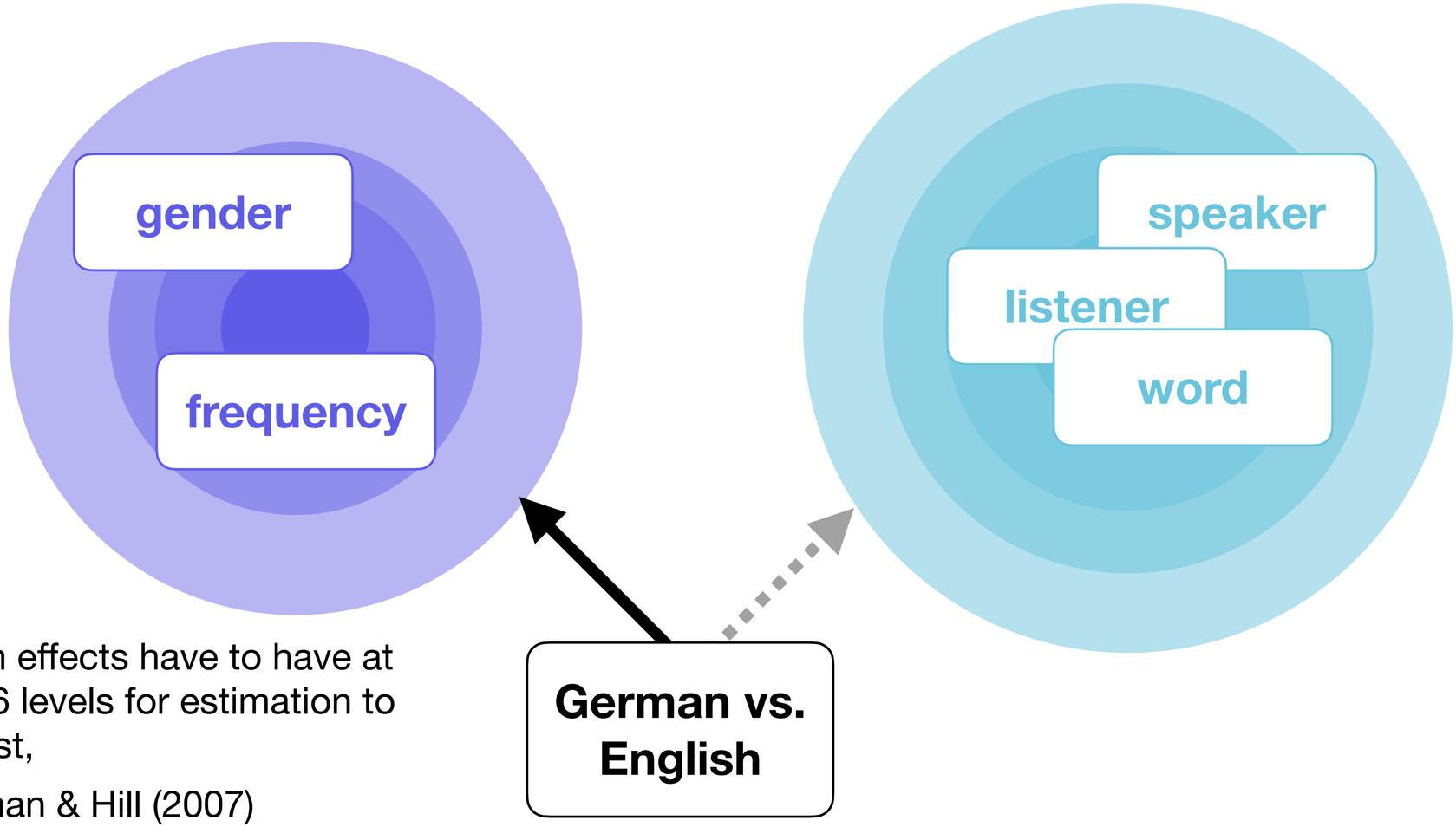


Random effects have to be categorical

“Fixed” vs. “Random” effects



“Fixed” vs. “Random” effects



Random effects have to have at least 5-6 levels for estimation to be robust,

cf. Gelman & Hill (2007)

Subject	Item	Condition
S1	1	Test
S1	2	Control
S1	3	Test
S1	4	Control
S2	5	Test
S2	6	Control
S2	7	Test
S2	8	Control

subjects-n = 20

item-n = 20

```
lmer(y ~ 1 + Condition +
                …
                …
```

Subject	Item	Condition
S1	1	Test
S1	2	Control
S1	3	Test
S1	4	Control
S2	5	Test
S2	6	Control
S2	7	Test
S2	8	Control

subjects-n = 20

item-n = 20

```
lmer(y ~ 1 + Condition +
                (1 + Condition | subject)
                  …
```

Subject	Item	Condition
S1	1	Test
S1	2	Control
S1	3	Test
S1	4	Control
S2	5	Test
S2	6	Control
S2	7	Test
S2	8	Control

subjects-n = 20

item-n = 20

```
lmer(y ~ 1 + Condition +
       (1 + Condition | subject)+
       (1 + Condition | item)
```

Subject	Item	Condition
S1	1	Test
S1	2	Control
S1	3	Test
S1	4	Control
S2	5	Test
S2	6	Control
S2	7	Test
S2	8	Control

subjects-n = 20

item-n = 20

```
lmer(y ~ 1 + Condition +
       (1 + Condition | subject)+
       (1 + Condition | item)
```

ELSEVIER

Journal of Memory and Language

Volume 68, Issue 3, April 2013, Pages 255-278

Random effects structure for confirmatory hypothesis testing: Keep it maximal

Dale J. Barr [a], Roger Levy [b], Christoph Scheepers [a], Harry J. Tily [c]

But maximal models might not “converge”

Model did not arrive at stable estimates.

That means, we **cannot trust** the results.

Practically, we **simplify random effect** structure until convergence.

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl =
## control$checkConv, : Model failed to converge with max|grad| = 1.52673
## (tol = 0.001, component 17)

## boundary (singular) fit: see help('isSingular')
```

Suggested workflow

1. Run **maximal** random effect structure, i.e. predictor slopes for all predictors for all grouping variables

```
lmer(y ~ 1 + Condition +
                        (1 + Condition | subject)+
                        (1 + Condition | item)
```

2. if it does not converge, remove one slope at a time and rerun until convergence.

```
## boundary (singular) fit: see help('isSingular')
```

```
lmer(y ~ 1 + Condition +
                        (1 + Condition | subject)+
                        (1 | item)
```

```
## boundary (singular) fit: see help('isSingular')
```

```
lmer(y ~ 1 + Condition +
                        (1 | subject)+
                        (1 | item)
```

Usually random intercept models converge fine

3. Transparently report the final model, remain sceptical and advice reader to be sceptical