

Mixed effects models 2

Even more bells and whistles

Samuel Robinson, Ph.D.

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Motivation

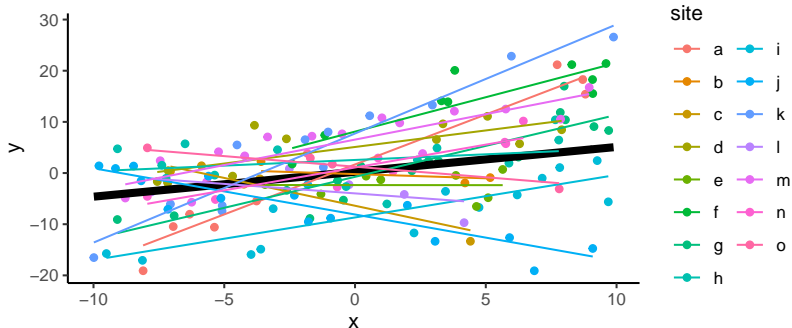
- How do I check if model results are valid?
 - Residual checks
 - Hypothesis testing
- What if my response variable is non-normal?
 - Generalized linear mixed models (GLMMs)
- Sampling over time or space
 - “Continuous” random effects
- Christmas-themed exercise!

Mixed effect model example

Let's go back to our earlier example:

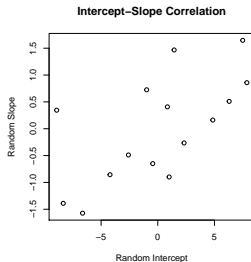
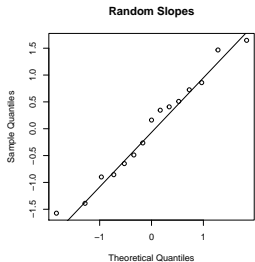
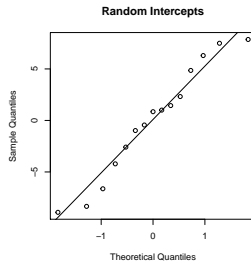
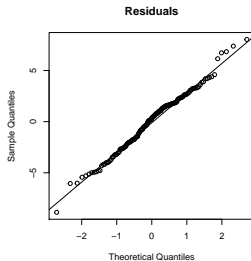
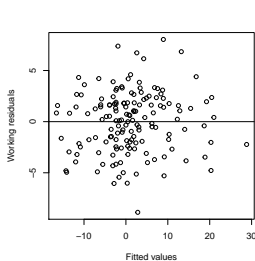
```
lmer(y ~ x + (x|site), data = dat)
```

- We're interested in predicting y using x (fixed effects)
- Data was collected at a number of *sites*, which may affect y
- Effect of each site is normally distributed (random intercept)
- Effect of site on slope of x is normally distributed (random slope)



Validation

- Similar to linear models, but we *also* check whether the random intercepts are normally distributed



Hypothesis testing

Is this fixed effect important? (e.g. ANOVA)

- Use likelihood-based test via drop1 (likelihood ratio test, AIC)
- Be careful to fit model with REML = FALSE!

```
mm1 <- update(mm1,REML=FALSE) #Refit model using ML rather than REML  
drop1(mm1,test='Chisq') #x has a very strong effect!
```

```
## Single term deletions
```

```
##
```

```
## Model:
```

```
## y ~ x + (x | site)
```

```
##           npar      AIC      LRT Pr(Chi)
```

```
## <none>      882.23
```

```
## x          1 883.36 3.1348 0.07664 .
```

```
## ---
```

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

Hypothesis testing (cont.)

How do I know this effect is different from x ? - Use Wald Z-test (2-sided p-value from Z-test)

```
##           x
## 0.06948193
```

- `glht` from `library(multcomp)` works with `lmer` models if you are comparing between coefficients (e.g. “Is treatment A different from B and C?”)

What if my response variable is non-normal?

Linear model (LM)

$$\hat{y} = X\beta$$

$$y \sim \text{Normal}(\hat{y}, \sigma)$$

Linear mixed effects model (LMM)

$$\hat{y} = X\beta + U\zeta$$

$$y \sim \text{Normal}(\hat{y}, \sigma)$$

$$\zeta \sim \text{Normal}(0, \sigma_{\text{site}})$$

Generalized linear model (GLM)

$$\text{logit}(\hat{\phi}) = X\beta$$

$$y \sim \text{Binomial}(\hat{\phi})$$

Generalized linear mixed effects model (GLMM)

$$\text{logit}(\hat{\phi}) = X\beta + U\zeta$$

$$y \sim \text{Binomial}(\hat{\phi})$$

$$\zeta \sim \text{Normal}(0, \sigma_{\text{site}})$$

How do I fit a GLMM?

- `glmer` and `glmer.nb` from `library(lme4)` work for Binomial, Poisson, and Negative Binomial data
- `glmmTMB` from `library(glmmTMB)` works for those above, *plus* a suite of others
 - e.g. Zero-inflation, Beta-binomial, Spatial Models