## Testing in Linear Mixed Models

To decide which LMM fits the data best we can use likelihood- based methods:

* Likelihood Ratio Test (LRT) => LRT can be used to test nested models (one is a special case of the other) based on the χ²-distribution
* Akaikes Information Criterium (AIC) combination of likelihood and # parameters used in the model (d.f.) model with the lowest AIC (high likelihood with few parameters) is deemed best
* **Problem with ML estimation:**
  + variance parameters (residual variance, variance(s) of random effect(s)) **biased downwards (smaller than they really are!) => UNDERestimating the variance**
  + Divide by **n**(ML) or **n-1** (REML)
* **Solution: REstricted (or: REsidual) Maximum Likelihood (REML)**
  + gives unbiased estimates of variance parameters
  + BUT: adjusts likelihood for number of covariates in model, so cannot be used to compare models that differ w.r.t. fixed parts of model

# Technical Issues – Mixed Models

**When to use ML x REML:**

* Testing models that differ in variance components: REML will give interpretable LRT, AIC so will ML
* Testing models that differ in fixed effects: only ML will give interpretable LRT, AIC
* Leading me to suggest the following model-building strategy:
  1. Start with full fixed model and (using ML estimation), select appropriate random part of model
  2. With the random part chosen, (using ML estimation) try to reduce fixed part of model
  3. Once you have your final model: run that model once more using REML; this is the model you present to your audience
* Testing random effect(s):
  1. variance parameters are never <0
  2. LRT (REML/ML) for random effects: chi-square test, **but divide p-value by 2**
  3. AIC also okay
* Testing fixed effect(s):
  1. LRT (ML only!) for fixed effects: chi-square test, usual p-value
  2. AIC okay (only under ML)

**Checking assumptions of the model**

* Model assumptions:
  + linearity (if we use time – or other covariates – as linear)
    - check with individual plots, spaghetti plots, residual plots
  + normality of residuals
  + normality of random intercepts (& slopes, if used)
    - these three can be saved and checked using Q-Q plots, boxplots, histograms
    - but: generally not helpful
      1. because deviations from normality probably not a big problem for inference on fixed effects (if your interest is in inference on random effects, there could be a problem)
      2. model ‘inflicts’ normality on the random effects, so normality of the estimated random effects may partly reflect model assumptions
  + independence of residuals (once fixed and random effects are taken into account) **CANT CHECK**
    - as in linear models: keep your fingers crossed!