

# Mixed-Effects Linear Regression model

A Linear Mixed-Effects (LME) model, also known as a Mixed-Effects Linear Regression model, is a statistical modeling technique used in the analysis of data, particularly when dealing with repeated measures or hierarchical data structures. LME models are an extension of the linear regression model and are particularly useful for situations where the assumption of independence among observations is violated.

Key features of Linear Mixed-Effects (LME) models:

**Fixed Effects:** Similar to traditional linear regression, LME models include fixed effects, which represent the population-level relationships between independent variables (predictors) and the dependent variable (response). These fixed effects are used to model the overall trends and relationships in the data.

**Random Effects:** The distinctive feature of LME models is the inclusion of random effects. Random effects account for the variability in the data that is not explained by the fixed effects. These random effects are used to model the individual variation or clustering within the data. For example, in a repeated-measures study, random effects can capture the individual-specific variations in responses over time.

**Hierarchical Data:** LME models are especially useful when dealing with hierarchical or nested data structures, such as multiple measurements on the same individuals or groups. The random effects account for the correlation or clustering of data points within these groups.

**Assumption of Independence:** LME models relax the assumption of independence between observations, which is often violated in situations where data points are correlated within groups or individuals.

**Variances and Covariances:** LME models estimate both the variance of the random effects and their covariances. This information helps quantify the extent of individual or group-specific variation.

**Modeling Heteroscedasticity:** LME models can account for heteroscedasticity, where the variability of the data is not constant across different levels of the independent variable.

LME models are widely used in various fields, including psychology, biology, social sciences, and many others. They are particularly valuable when dealing with data that involves repeated measurements, clustering, or when researchers want to account for individual-level variations in a more sophisticated manner than traditional linear regression models.

To fit an LME model, statistical software such as R, Python (with libraries like statsmodels or lme4), or specialized software for mixed-effects modeling is often used. The results of an LME model provide information about fixed effects, random effects, and the extent to which these components explain the variability in the data.

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