1.22 Expected mean squares (EMS)

An important consequence of the choice made for each factor as to whether it be fixed or random is identified by examining the *expected mean squares (EMS)* for each term in the resulting model. This is vitally important because the EMS's are used to identify an appropriate denominator mean square that one must use for each particular term in the model in order to construct a correct pseudo-*F* ratio that will isolate that term of interest for the test. For univariate ANOVA, the underlying theory for deriving expectations of sums of squares and mean squares is covered well elsewhere (e.g., Cornfield & Tukey (1956) , Hartley (1967) , Rao (1968) , Winer, Brown & Michels (1991) , Searle, Casella & McCulloch (1992)). PERMANOVA actually uses the same "rules" for constructing these expectations, implementing these as a direct multivariate analogue to the univariate approach.

The default rules used by PERMANOVA assume that fixed effects sum to zero, following Cornfield & Tukey (1956) and Winer, Brown & Michels (1991) . Some constraint on fixed effects is necessary, due to the intrinsic over-parameterisation of the ANOVA model (e.g., Scheffé (1959)), and the sum-to-zero constraint is a highly convenient one. The constraint chosen does not affect the sums of squares. It does, however, affect the EMS's and thus the *F* ratios and *P*-values that are obtained for ANOVA mixed models. Some well-known computer packages for univariate statistics relax the sum-to-zero constraint for fixed effects in mixed interactions, including SPSS and the 'proc GLM' routine in SAS. To obtain EMS's in accordance with these packages, remove the $\checkmark$ in front of the 'Fixed effects sum to zero' box in the PERMANOVA dialog. See Hartley & Searle (1969) , Searle (1971) , Hocking (1973) , McLean, Sanders & Stroup (1991) and Searle, Casella & McCulloch (1992) for further discussion and debate regarding this issue.

Once the individual components of variation have been identified, then the expectations of the mean squares for each term in the model are determined precisely in terms of these components, and are provided in the output under the heading '*Details of the expected mean squares (EMS) for the model*'. Thus, we can see, for example (Fig. 1.23), that the expectation for the mean square calculated for the term 'Block' (abbreviated as 'Bl' in the output) is one times the residual variation plus four times the variation due to blocks (denoted as '1*V(Res) + 4*V(Bl)' in the output). *Each term in the model will have an expected mean square that consists of some linear combination of the components of variation in the model*.

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