$$\text{Efficiency} = \frac{\left(\dfrac{n_2C_2}{\hat{\sigma}_1^2}\right)\left(\dfrac{\text{df}_1 + 1}{\text{df}_1 + 3}\right)}{\left(\dfrac{n_1C_1}{\hat{\sigma}_2^2}\right)\left(\dfrac{\text{df}_2 + 1}{\text{df}_2 + 3}\right)},$$

where $\hat{\sigma}^2$ = estimate of experimental error per observation, n = number of subjects, C = cost of collecting data per subject, df = experimental error degrees of freedom, and the subscripts designate the two experimental designs (Federer, 1955, 13). If the ratio is less than one, the second design is more efficient than the first. The converse is true if the ratio is greater than one. The formula calls attention to four factors that are related to the efficiency of experimental designs. Unfortunately, an experimental design that is advantageous with respect to one factor may not be advantageous with respect to the others. For example, if a design has the desirable attribute of a small experimental error, it may have a high cost per subject or a small number of degrees of freedom for experimental error, or it may require a large number of subjects. The problem facing an investigator is to select an experimental design that represents the best compromise obtainable within the constraints of his research situation.

DETERMINATION OF SAMPLE SIZE

Once the independent and dependent variables are specified, the number of subjects required for the experiment must be determined. This is one of the more perplexing problems in experimental design. Five factors must be considered in specifying a sample size that is adequate for testing a statistical hypothesis: (1) minimum treatment effects an experimenter is interested in detecting, (2) number of treatment levels, (3) population error variance, (4) probability of making a type I error, and (5) probability of making a type II error. In general, the population error variance is unknown. It may be possible to make a reasonable estimate of the population error variance on the basis of previous experiments or a pilot study. If the above information can be specified, the size of the sample necessary to achieve a given power can be calculated. The power of a research methodology is defined as the probability of rejecting the null hypothesis when the alternative hypothesis is true. Power is equal to 1 − (probability of committing a type II error).

The procedure described here for calculating power was developed by Tang (1938). It assumes that the observations are normally distributed with a common error variance = σ_ε^2. The parameter ϕ is defined as

$$\phi = \frac{\sqrt{\sum_1^k(\mu_j - \mu)^2/k}}{\sigma_\varepsilon/\sqrt{n}},$$