GLIMMPSE User Manual

Version 2.1.0

Authors:
Zacc Coker-Dukowitz, Brandy Ringham, and Sarah Kreidler

March 2014

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GLIMMPSE is released under the GNU Public License version 2.0. GLIMMPSE Version 2.1.0 is funded by NIDCR 1 R01 DE020832-01A1 to the University of Florida (Keith E. Muller, PI; Deborah Glueck, University of Colorado site PI). Previous funding was received from an American Recovery and Re-investment Act supplement (3K07CA088811-06S) for NCI grant K07CA088811.

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1. Introduction

1.1. Version Information and Licensing

This manual describes version 2.1.0 of the GLIMMPSE software. The manual applies to all 2.1.x versions of GLIMMPSE (e.g. 2.1.0, 2.1.1, 2.1.2, etc.).

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1.2. Welcome to GLIMMPSE 2.1.0

GLIMMPSE 2.1.0 is an open-source online tool for calculating power and sample size. GLIMMPSE has been designed so that researchers and scientists with a varying levels of statistical training can have access to reliable power and sample size calculations. For optimum usability, GLIMMPSE provides two different modes. In *Guided Mode* users receive step-by-step guided instructions for entering data in order to obtain power and sample size outputs. In *Matrix Mode* users receive less guidance, and are assumed to possess in-depth statistical training.

GLIMMPSE can compute power or sample size for univariate and multivariate linear models with Gaussian errors Muller and Stewart (2006). GLIMMPSE supports two main types of study design models: designs with only fixed predictors, and designs with fixed predictors and a single Gaussian covariate. The values of a fixed predictor are set as part of the study design, and are known without appreciable error. In contrast, Gaussian covariates are not observed until data is collected. Common designs with only fixed predictors include t-tests, analysis of variance (ANOVA), and multivariate analysis of variance (MANOVA). Common designs that control for a covariate include analysis of covariance (ANCOVA) and multivariate analysis of covariance (MANCOVA).

Details about power calculations for the general linear multivariate model with Gaussian data and fixed predictors can be found in (Muller and Peterson 1984), (Muller and Barton 1989), (Muller, Lavange, Ramey, and Ramey 1992), (Muller, Edwards, Simpson, and Taylor 2007), (Muller and Stewart 2006), and (Muller *et al.* 2007). Details for fixed predictors with a single Gaussian covariate can be found in (Glueck and Muller 2003).

GLIMMPSE utilizes a Java web services architecture (McGovern, Tyagi, Stevens, and Mathew 2003), designed to facilitate future support of additional statistical models. The tool is hosted at .

1.3. Why GLIMMPSE?

Other programs, such as POWERLIB, NQuery, and Pass, also calculate power and sample size. So why use GLIMMPSE?

GLIMMPSE has several advantages over these other programs, because GLIMMPSE:

1. **Is free**. GLIMMPSE provides free online power and sample size computing.
2. **Is user friendly**. In both *Guided Mode* and *Matrix Mode* GLIMMPSE provides a step-by-step interface to assist researchers in producing accurate power and sample size calculations.

3. Calculates power and sample size for any univariate or multivariate test for the general linear multivariate model, assuming fixed predictors.
4. Produces confidence intervals on power estimates for designs with fixed predictors.
5. Produces power and sample size calculations for designs with a single Gaussian covariate.
6. Supports designs with unequal group sizes, and complicated covariance structures.
7. Creates basic power curves.

2. Using GLIMMPSE

2.1. When to Use GLIMMPSE

GLIMMPSE is a tool researchers and scientists can use to calculate reliable values for power and sample size. GLIMMPSE calculates power or sample size for designs with normally distributed outcomes, and for a variety of multilevel and longitudinal studies. GLIMMPSE can calculate power and sample size for common statistical tests and models including:

- One sample t-test
- Paired t-test
- Two sample t-test
- Analysis of variance (ANOVA)
- Analysis of covariance (ANCOVA)
- Repeated measures analysis of variance
- Multivariate analysis of variance (MANOVA)
- Multivariate analysis of covariance (MANCOVA)

2.2. How to Use GLIMMPSE

2.2.1. Initiating the GLIMMPSE Wizard

GLIMMPSE can be accessed with a standard web browser at . The GLIMMPSE start screen is shown in Figure 1. GLIMMPSE has been tested in Internet Explorer 8 (Microsoft 2010), Mozilla Firefox 13.0.1 (Mozilla 2011), Google Chrome 23.0.1271.95 (Google 2011) and Safari 5.0.3 (Apple 2010).

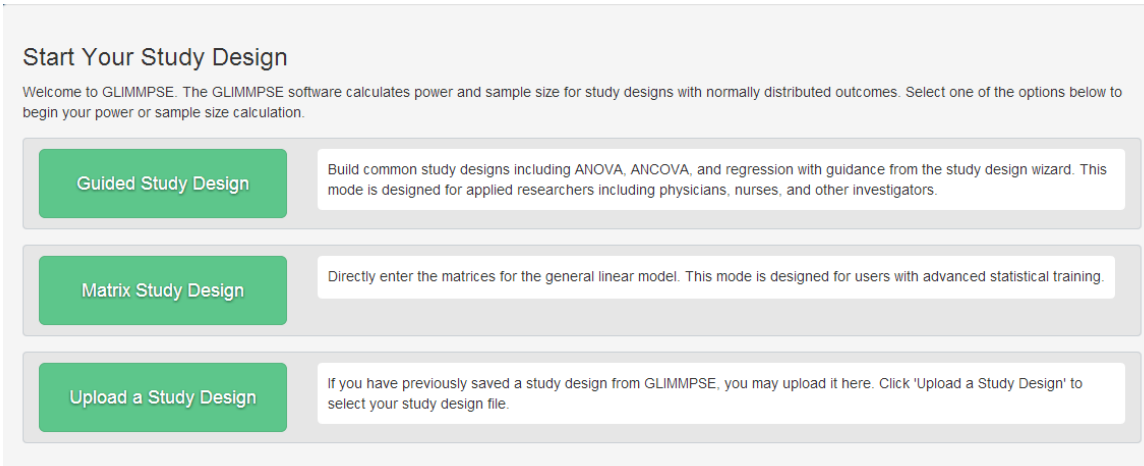


Figure 1: GLIMMPSE Start Screen

2.2.2. Choosing Between Guided Mode and Matrix Mode

The GLIMMPSE start screen presents three options: *Guided Mode*, *Matrix Mode*, and *Upload a Study Design*.

In *Guided Mode* users receive step-by-step guided instructions when entering inputs for power or sample size calculations. To choose Guided Mode, click the Guided Study Design box.

In *Matrix Mode* users receive less guidance, and are assumed to possess in-depth statistical training. *Matrix Mode* allows direct input of all matrices required for a power or sample size calculation. To choose Matrix Mode, click the Matrix Study Design box.

If the user has a study design saved from a previous GLIMMPSE session, the user may upload it by clicking the *Upload a Study Design* box. GLIMMPSE will open the saved study design and allow the user to continue the power or sample size analysis.

2.3. Basic Navigation for GLIMMPSE in Both *Guided Mode* and *Matrix Mode*

Once a mode of entry has been chosen, the steps required for GLIMMPSE to calculate power are listed as tabs on the left side of the *Introduction* screen. A white background indicates a tab as active, and a blue background designates a tab as inactive. Blue text designates a page within a tab as active, and gray designates a page as inactive. Only one page within one tab can be active at a time.

On the upper right of any screen in GLIMMPSE is a menu of options enabling users to save their study design by clicking Save, consult the help library by clicking Help, or cancel without saving and return to the *Start Your Study Design* screen by clicking Clear.

Each section is broken into one or more sub-sections with the title in bold at the top of the page. Each screen contains instructions and/or areas for user inputs. Users navigate by clicking on the section titles and sub-sections in the left navigation panel.

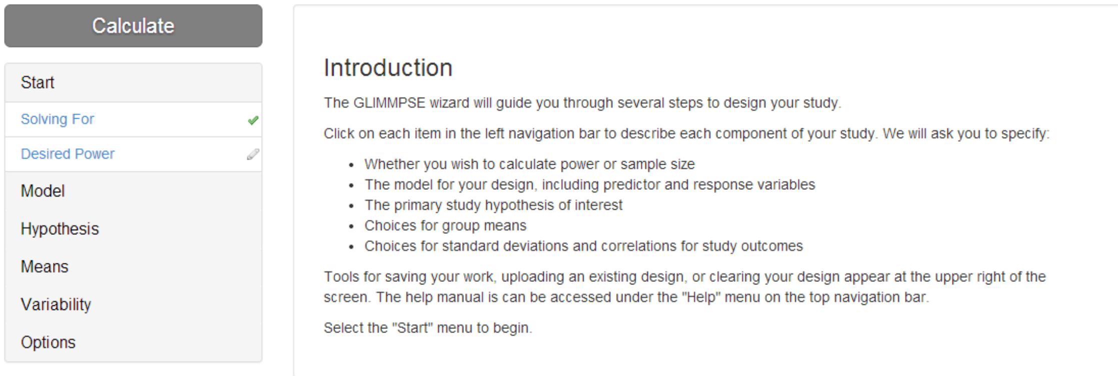


Figure 2: Example Start Screen

Following the *Introduction* screen (Figure 2), GLIMMPSE will prompt the user to enter the details for the power or sample size calculation. The user may enter the details in any order. However, some screens cannot be accessed unless the user has completed information from previous screens. For example, if the user has not entered information in the *Response Variables* tab, then the user will not be able to enter information in the *Hypothesis* tab. If a tab is inaccessible due to missing information in an earlier screen, it will be indicated by a grey circle with a slash through it :

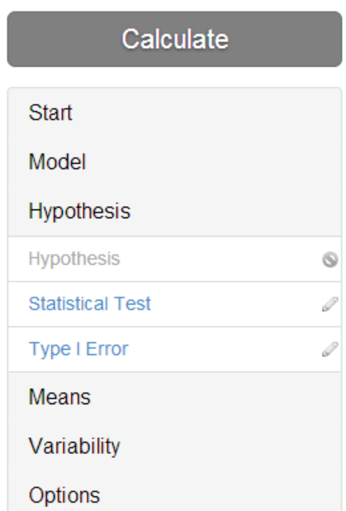


Figure 3: More information is required to access the *Hypothesis* screen.

Notice that in Figure 2 above there are pencil icons beside the *Desired Power* screen in the active *Start* tab. The pencil icons indicate screens which require additional information. Once the user have entered the required information, the pencil will turn into a green check mark, as shown in Figure 4.

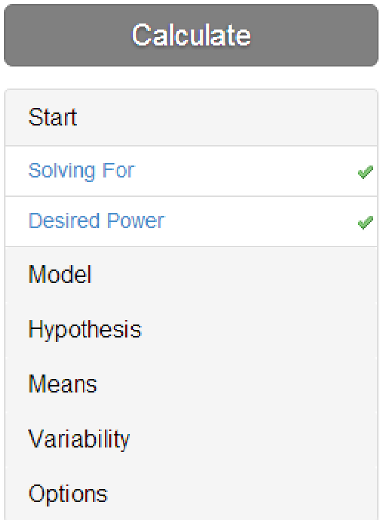


Figure 4: Indication that the *Solving for* screen is complete.

Some screens are optional, and will already have a check mark beside them.

2.3.1. Typing Into a Text Box

Several screens in GLIMMPSE will ask you to specify information by typing into a text box. To input information in a text box, click in the text box and type the requested information. To complete the entry you may press Enter on your keyboard.

To delete entries in a list associated with the text box, click ✖ to delete the entry.

Figure 5 shows three examples of text box entries with the text boxes highlighted in blue.

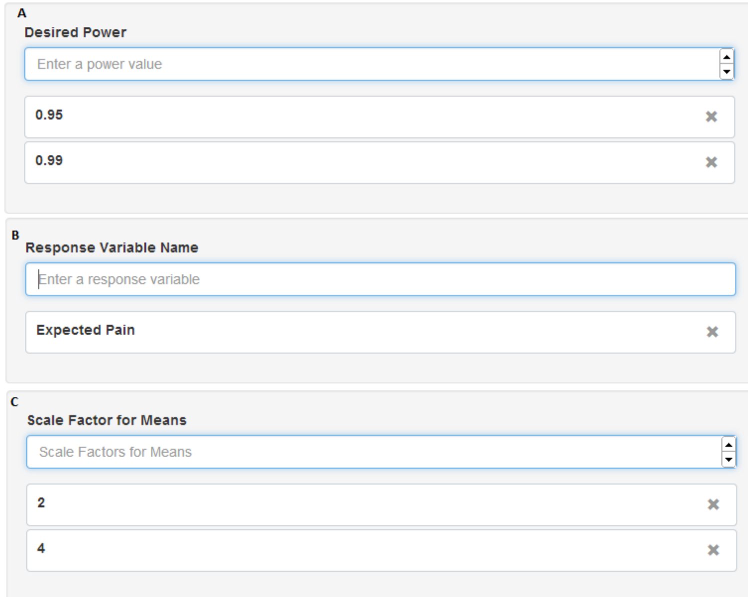


Figure 5: Examples of text boxes that are used to A) list the desired power values; B) enter response variables name; and C) specify scale factors for means.

2.3.2. *Using Drop Down Lists*

When GLIMMPSE requires you to choose from a defined list of options, these options will be presented in a drop down list. Figure 6 shows an example of a drop down list. To choose an option from a drop down list, click on the down arrow (see [1]), then select your choice from the list of options (see [2]).

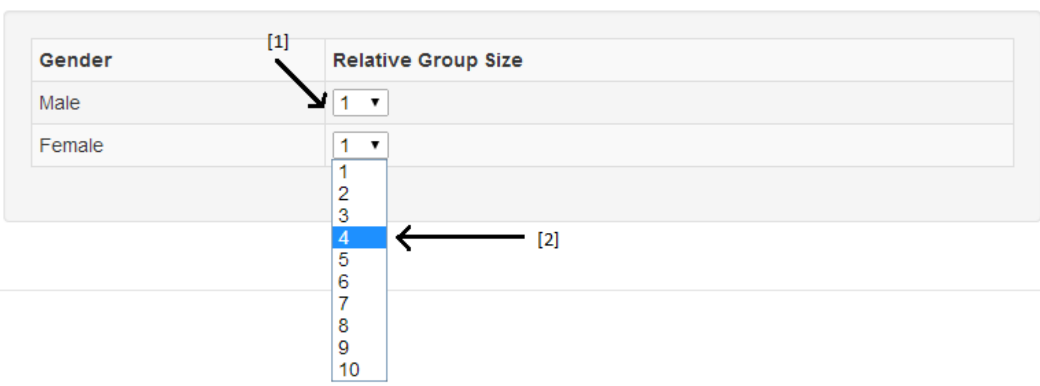


Figure 6: Example of a drop down menu.

2.3.3. *Radio Buttons and Check Boxes*

In some cases, you must choose from a list of options by selecting a radio button or checking a box. The radio buttons allow you to select only one option. The check boxes allow you to select more than one option. To select an option, click on the radio button or check the box next to that option. Figure 7 shows an example of a radio button (see A), and a check box (see B).

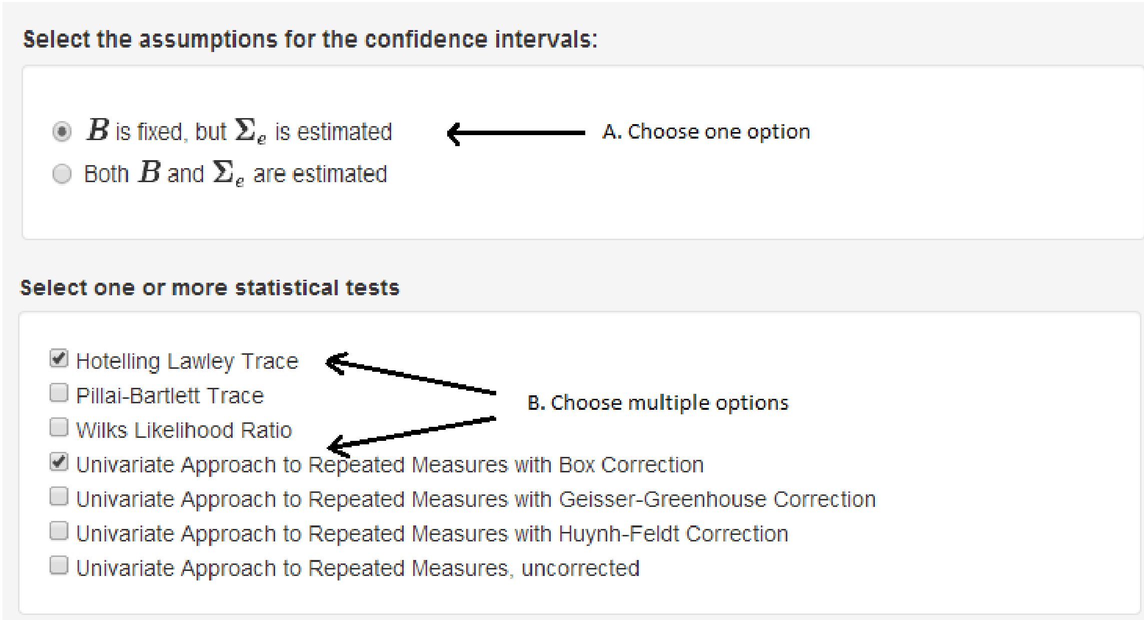


Figure 7: Example of radio buttons and check boxes.

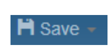
2.3.4. Results Report

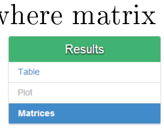
Power results are displayed in a table with each row representing an individual power calculation. If multiple factors have been specified in the study design (for example, multiple Type I error rates, variability scale factors, etc.) then the results table will have multiple rows. See Table 1 below for an example of the information displayed for a given results report.

Every results report for power contains both calculated and desired power values. When solving for power, these two values are the same. When solving for sample size, it may not be possible to achieve the exact power value specified by the user. In this case, *Target Power* is the default power value (the power value specified by the user), and *Power* is the calculated power for the sample size that best matches the desired power.

A power curve may also be requested, with power on the vertical, or Y, axis and either the regression coefficient scale factor, covariance scale factor, or total sample size on the horizontal, or X, axis.

Power results can be saved to a comma delimited file so that users can import the data into other statistical packages. To save the power results, click 

from the 

menu on the upper right corner of the screen. For transparency, the matrices used in the calculations are accessible on the results screen. This is most useful in *Guided Mode*, where matrix information is largely hidden from the user. To view the exact matrices used in the calculations, click 

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Column Name	Description
Power	Calculated power
Confidence Limits	Lower and Upper limits of the 95% confidence interval
Total Sample Size	Total number of research participants required to achieve the actual power
Target Power	The desired power
Type I Error Rate	The Type I error value
Test	Name of the statistical test
Means Scale Factor	Scale factor applied to the $\mathbf{B}$ or $\mathbf{B}_F$ matrix
Variability Scale Factor	Scale factor applied to the $\mathbf{\Sigma}_E$ matrix
Power Method	Indicates whether conditional, unconditional, or quantile power was used
Quantile	If the current power method is quantile power, this indicates the quantile of the distribution of possible powers. Otherwise, this field is empty.

Table 1: Information displayed for each power result.

2.4. Basic Navigation for *Guided Mode*

2.4.1. Entering Predictor Variables

In Guided Mode, GLIMMPSE requires the user to enter labels for predictor variable(s) (also called independent variables) and outcome variable(s) (also called dependent variables). Figure 8 shows an example of entering variable labels. To enter a variable label, type the label into the text box provided (see [1] in Figure 8). After each entry, press Enter on the keyboard.

For the predictor variables, GLIMMPSE also asks the user to specify the categories for each variable. For example, the predictor variable "gender" has two categories, "male" and "female." To specify categories associated with a given predictor, select a predictor in the text box on the left (see [2]), then enter the category labels into the text box on the right (see [3] in Figure 8). After each entry, press Enter on the keyboard.

Only category labels associated with the highlighted predictor label are shown. To delete predictors or category labels, select the unwanted label and click ✖. This removes the label from the list. If the user removes a predictor, the associated categories are automatically deleted.

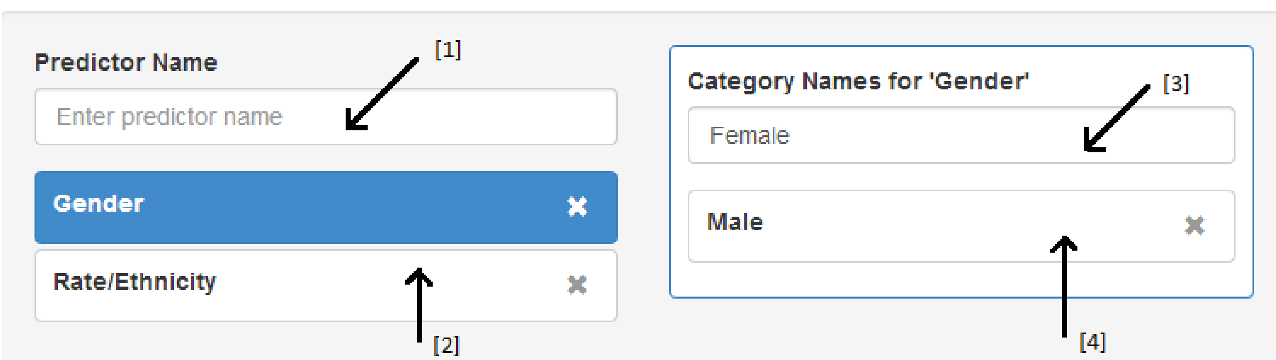


Figure 8: Example of entering labels

2.5. Basic Navigation for *Matrix Mode*

2.5.1. Resizing and Entering Values Into a Matrix

In Matrix Mode, GLIMMPSE requires the user to define the matrices for the power calculation. Figure 9 shows an example of a matrix template in *Matrix Mode*. Sometimes the matrix dimensions are pre-determined. If not, the user can set the matrix dimensions by typing the number of rows into the row text box (see [1] in Figure 9) and the number of columns into the column text box (see [2] in Figure 9). Fill in the elements of the matrix by entering values into the text boxes within the matrix template (see [3] in Figure 9).

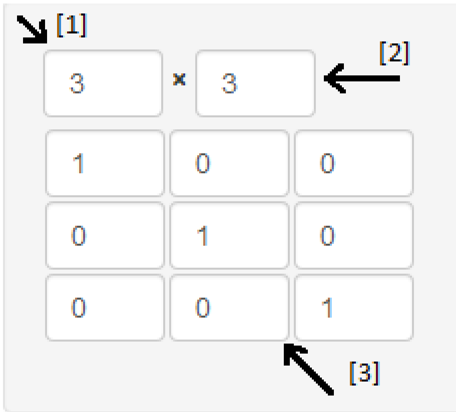


Figure 9: Example of entering values into a matrix

3. Using *Guided Mode: A Screen-by-Screen Tour*

In *Guided Mode* users receive step-by-step guided instructions when entering inputs for calculating power and sample size for use in study design.

3.1. Start

3.1.1. Introduction

The *Introduction* screen contains a summary of the steps involved in the power or sample size analysis.

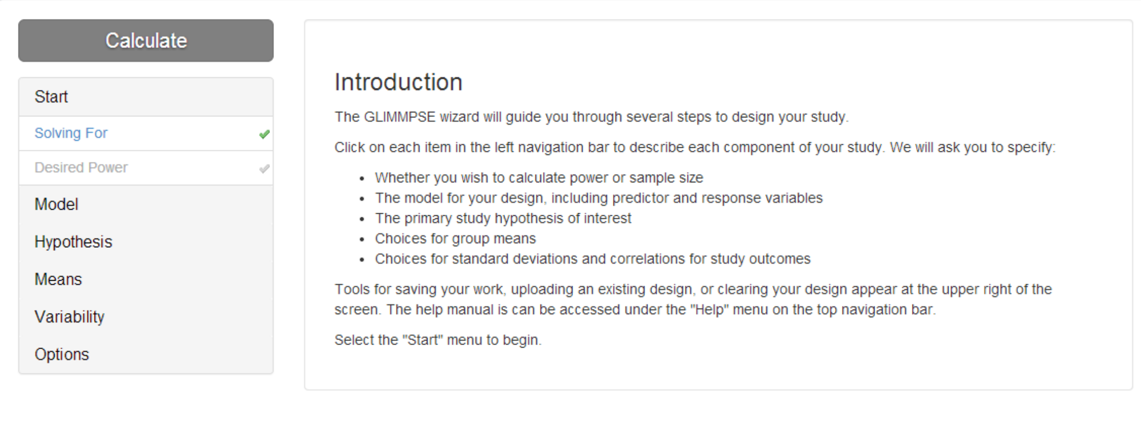


Figure 10: Introduction Screen

3.1.2. Solving For?

The *Solving For?* screen allows the user to select either a power or sample size calculation.

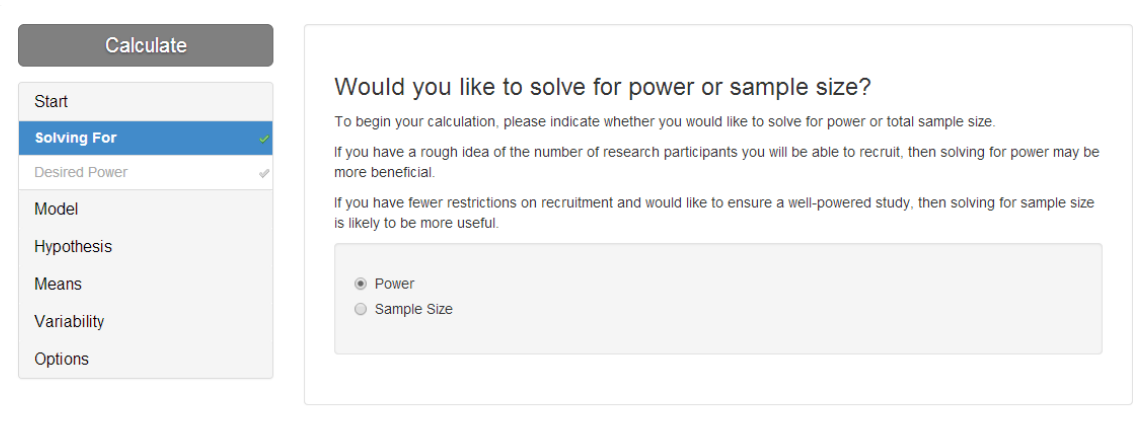


Figure 11: Solving For? Screen

When *power* is selected, the inputs will be used for a power analysis. The power analysis will produce a value(s) between 0 and 1, representing the probability the study will provide an answer to the question of interest. When *sample size* is selected, the inputs will be used to calculate the number of individual sampling units (also called participants, if referring specifically to people) needed for the study to achieve the desired power.

If the number of participants is not set, we recommend solving for sample size in order to obtain the appropriate sample size for achieving the goals of your study. However, if the sample size is set due to budgetary or other restrictions, a power calculation will indicate the probability that your study will provide a definitive answer to the question of interest.

On the screen, select *Power* or *Total Sample Size* by selecting the appropriate radio button.

3.1.3. Desired Power (if solving for Total Sample Size)

When solving for sample size, the user must enter the desired power for the study. Enter the target values as decimals, i.e. 0.95, in the Power Values box and press Enter on the keyboard to add the value to the list.

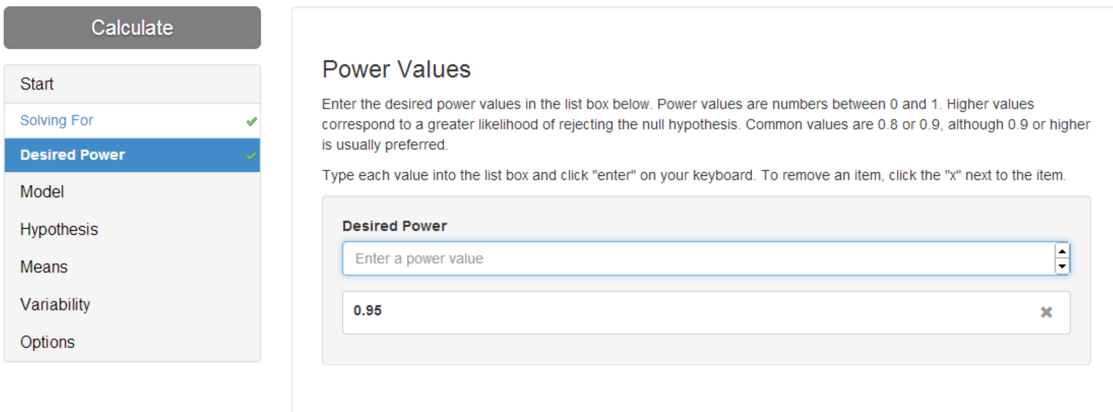


Figure 12: Desired Power Screen

3.2. Model

3.2.1. Introduction

This screen provides an introduction to the *Model* section and defines the concept of an independent sampling unit. The sampling unit is typically the study participant. For multilevel designs and cluster randomized trials, the sampling unit may be a group of participants, such as schools or neighborhoods.

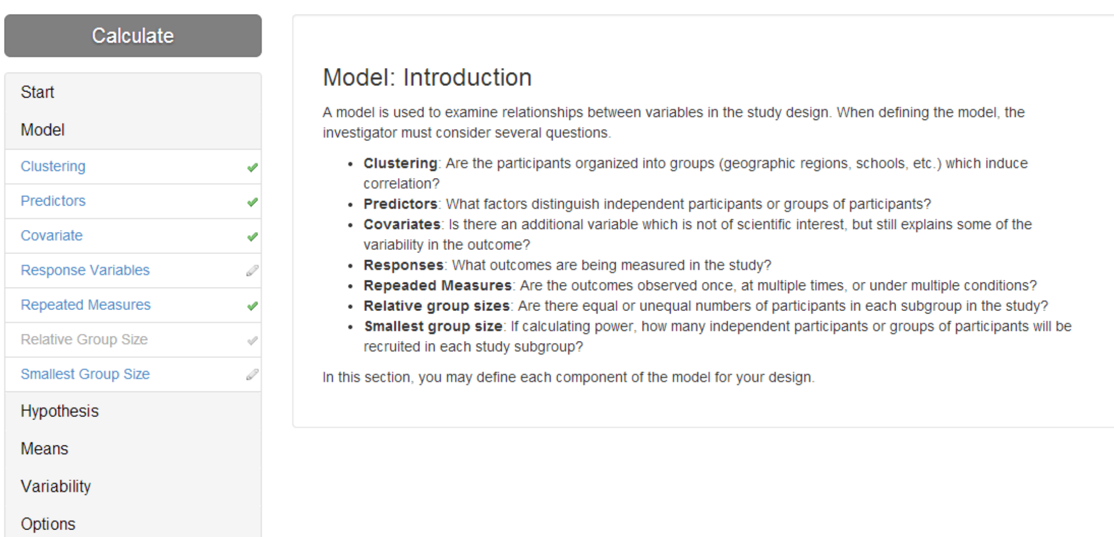


Figure 13: Sampling Units: Introduction Screen

3.2.2. *Clustering*

Clustering is present when research participants are organized into groups. Often, randomization in a study occurs at the group level rather than by individual research participants. The *Clustering* screen allows the user to enter up to three levels of clustering.

An example of clustering would be a study design in which the participants are students randomly selected from different schools in an area. In this case, each school would represent a cluster. An example of subgroups within a cluster would be each classroom within a given school.

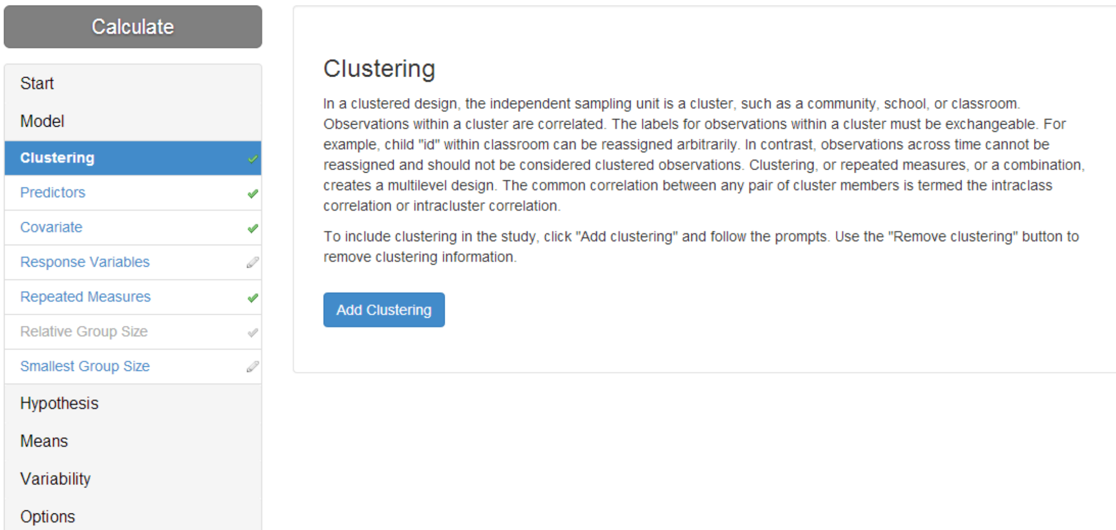


Figure 14: Clustering Screen

If the study design does not include clustering, simply click on other sub-sections to proceed.

To add clustering, click the *Add clustering* button. Three text boxes will appear at the bottom of the screen:

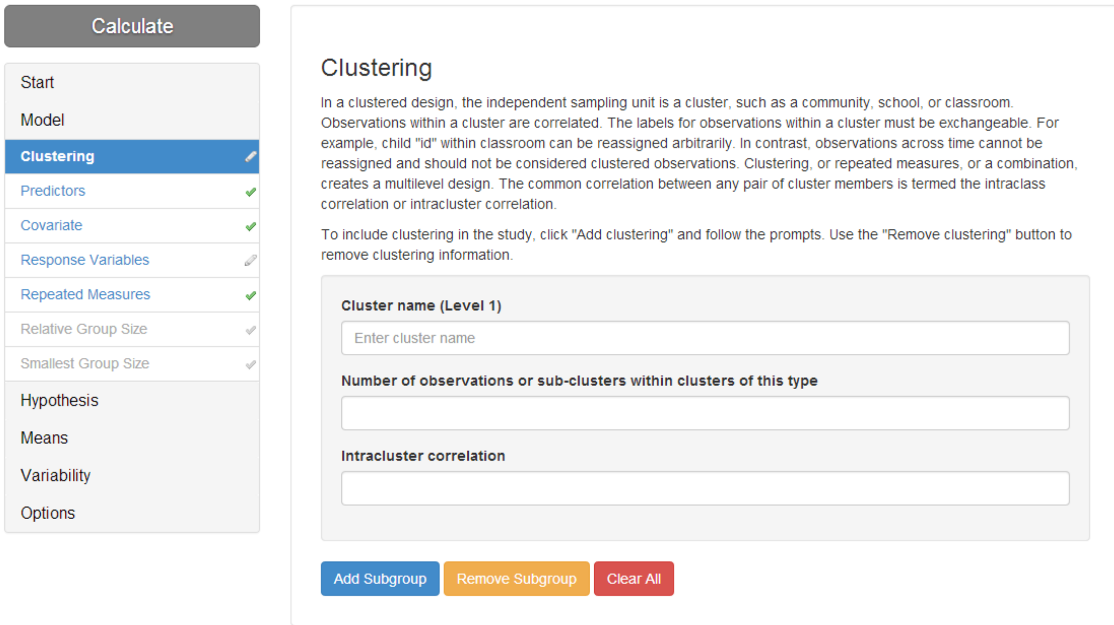


Figure 15: Clustering Options

Enter the *Cluster name*, specify the *Number of observations or sub-clusters within each cluster of this type*, and specify the *Intra-cluster correlation*. The Intra-cluster correlation is the expected correlation between pairs of observations within the cluster.

To add a subgroup to the cluster, click *Add subgroup* and fill in the information for that subgroup. GLIMMPSE allows one primary cluster and two subgroups.

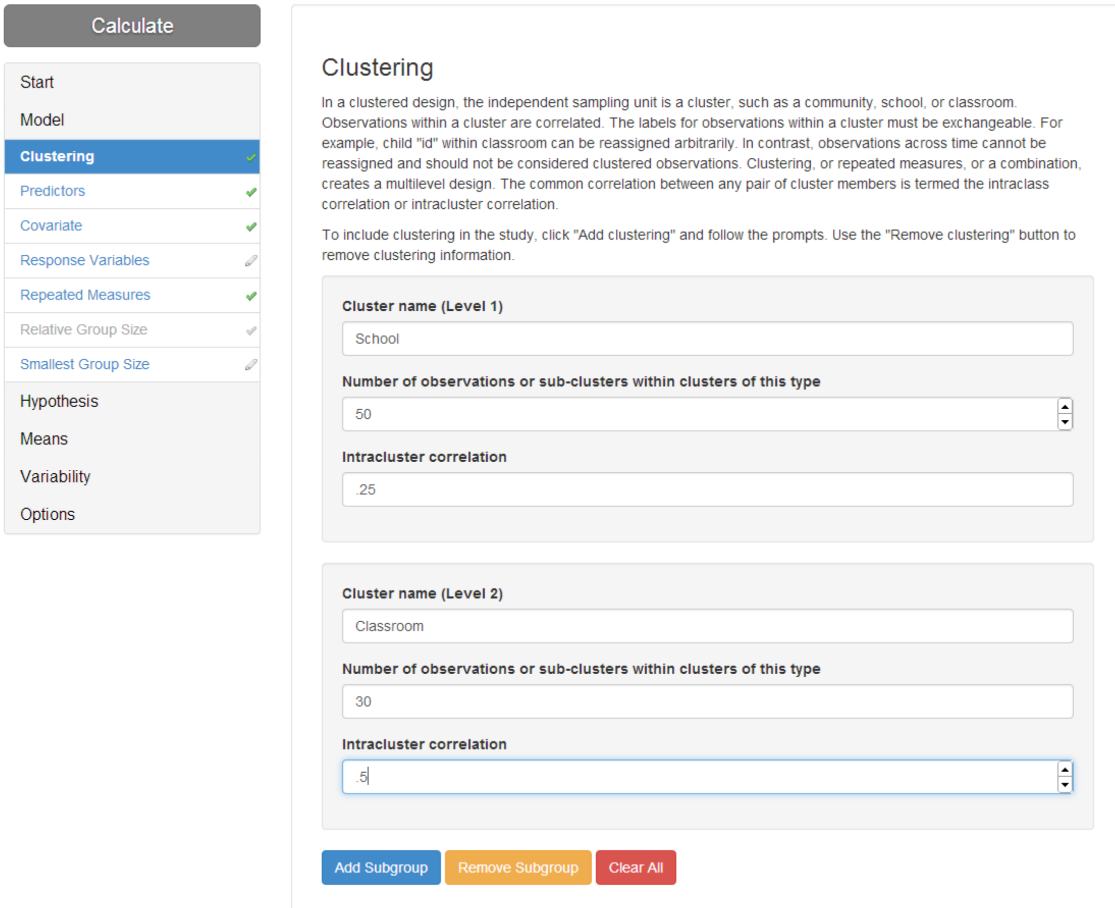


Figure 16: Clustering Sub-Groups

Continuing with the above example, the subgroup *Cluster name* would be "classroom," the *Number of observations* would be the number of students within each classroom, and the *Intra-cluster correlation* would be the expected agreement between students within each classroom.

To remove a subgroup or remove clustering, simply click *Remove subgroup* or *Clear All*.

3.2.3. Predictors

Independent sampling units may be randomized to different treatments, or be classified by characteristics such as gender. The characteristics divide the sampling units into study groups. The *Predictors* screen allows the user to define the study groups by specifying *fixed predictors*. Enter the fixed predictors as described in Section 2.4.1. For one-sample designs with no fixed predictors, leave the table blank.

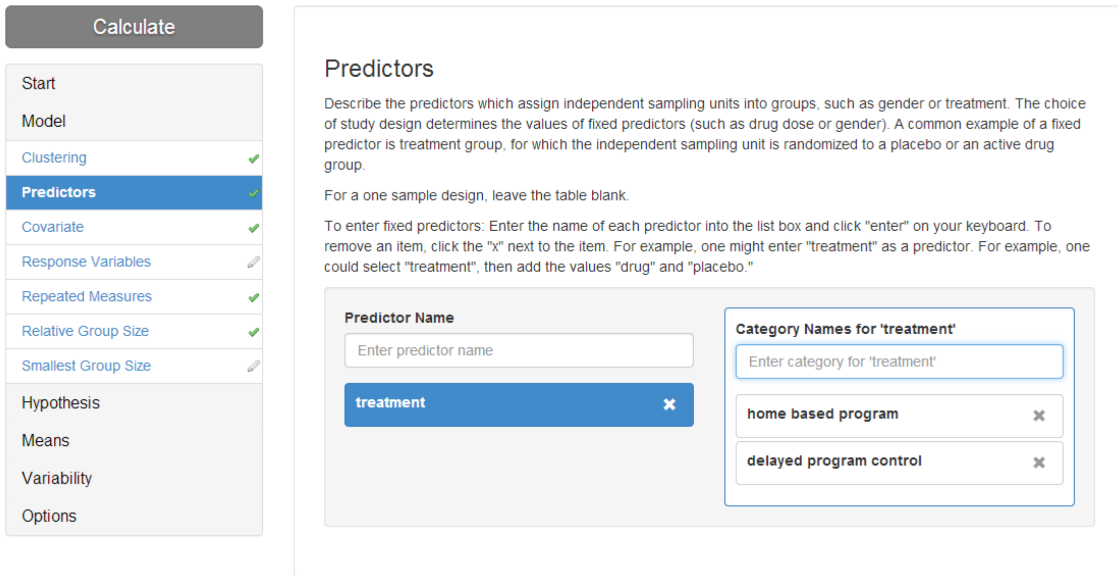


Figure 17: Predictors Screen

3.2.4. *Covariate*

The *Covariate* screen allows the user to control for a single, normally distributed predictor (also known as a normally distributed covariate). For example, a scientist may wish to examine the effect of a drug when controlling for age. In this case, age would be the covariate. If the study design does not include a normally distributed predictor, leave the checkbox blank. If the study design does include a covariate, check the checkbox.

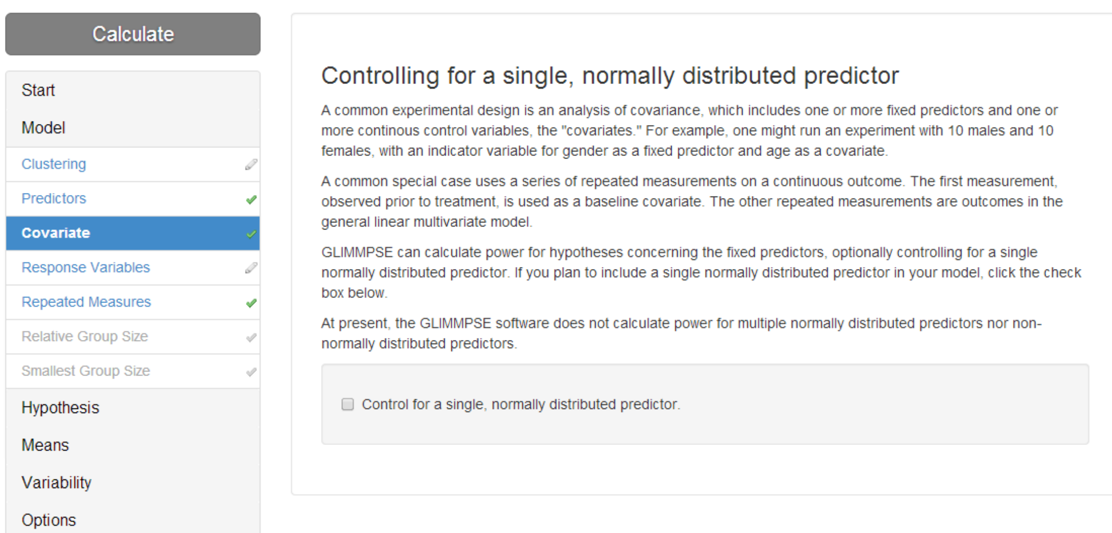


Figure 18: Gaussian Predictor Screen

3.2.5. Response Variables

The *Response Variables* screen allows the user to specify the response or dependent variables for the study. For example, if "expected pain" is the desired outcome, enter "expected pain" in the text box.

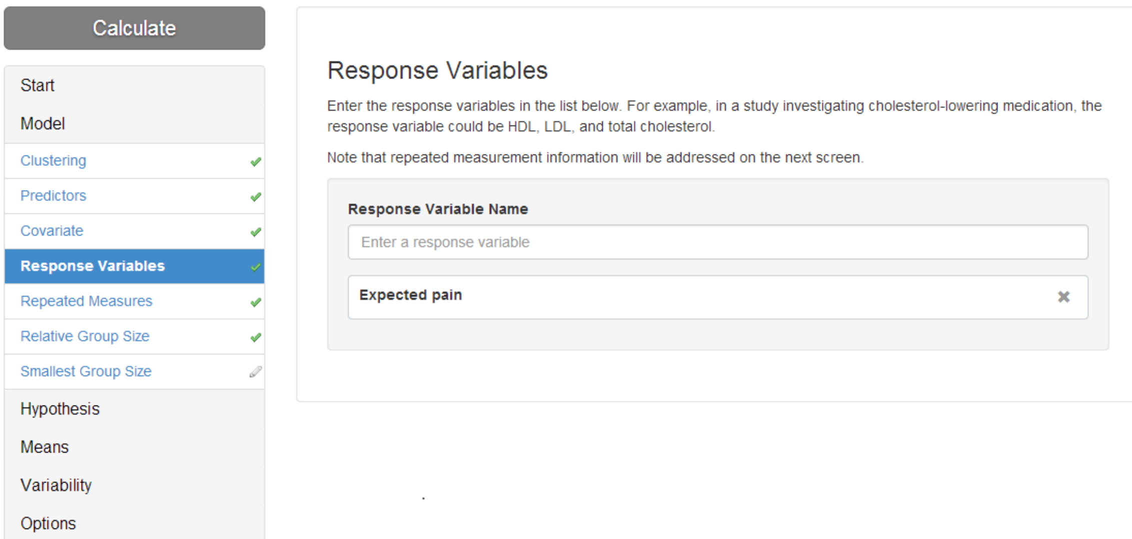


Figure 19: Response Variables

3.2.6. Repeated Measures

The *Repeated Measures* screen allows the user to describe repeated measures. Repeated measures are present in a study when multiple measurements are taken on each research participant. An example of repeated measures would be researchers taking a participant's blood pressure once a month for six months.

If the design does not have repeated measures, simply click on other sub-sections to proceed. If the design includes repeated measures, click *Add repeated measures* and fill in the requested information.

Units is a user-specified description of the repeated measure. For example, if the repeated measures are taken once every month, the unit could be "month." Enter a label for the units of the repeated measure.

Enter the *Type* of unit. For *Numeric* repeated measures, both the distance and ordering between measurements is meaningful. Measuring blood pressure every month for 6 months is a numeric repeated measure. GLIMMPSE will auto-populate an equal distance between repeated numeric measures. You can change the distance between the measures by typing into the text boxes. For *Ordinal* repeated measures, the ordering of the measurements is meaningful, but the distance between measurements is assumed to be equal. For example, repeated measures of the participant's heart rate taken in the morning, afternoon, and evening. For *Categorical* repeated measures, neither the ordering nor the distance between the measures is meaningful. For example, repeated measures of breast density using three different instruments, Device A, B, and C.

Number of Measurements allows you to specify the number of times the repeated measure will be taken. For the blood pressure example, the *Number of Measurements* would be 6 because blood pressure was measured every 6 months. For numeric repeated measures, GLIMMPSE 2.0 auto-populates equidistant measurements. To change the distance between measures, type into the text boxes. For example, if blood pressure was measured every month for the first three months, then every other month for the next six months, the user would type 1, 2, 3, 5, 7, 9 into the text boxes.

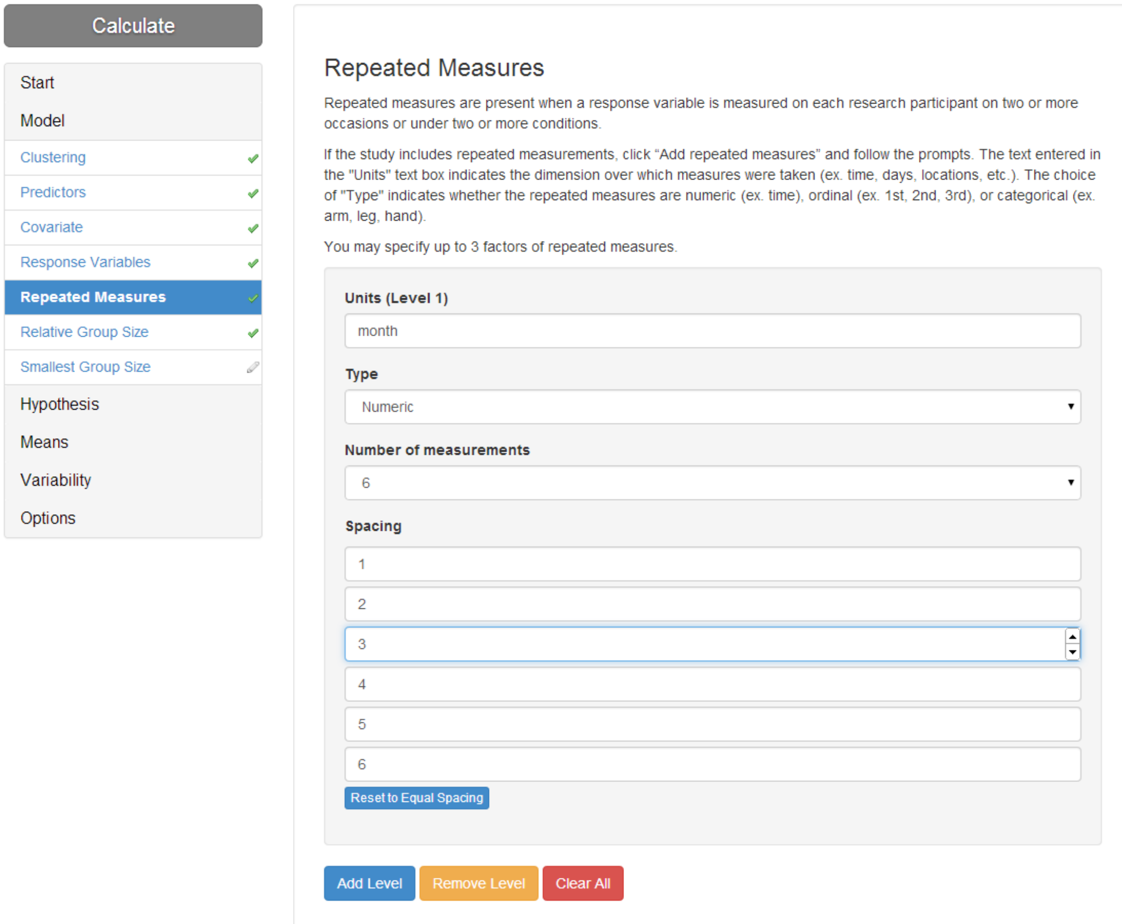


Figure 20: Repeated Measures

Nested repeated measures are added via the *Add Level* button. For example, consider a design in which a participant's blood pressure is measured every month for six months, and at each visit in three different positions (for example, standing, sitting, and supine). The design would include doubly repeated measures with one level for "month" and a second nested level for "position." The user may add up to three levels of repeated measures.

To add a sub-level, click the *Add level* button. Three more text boxes will appear:

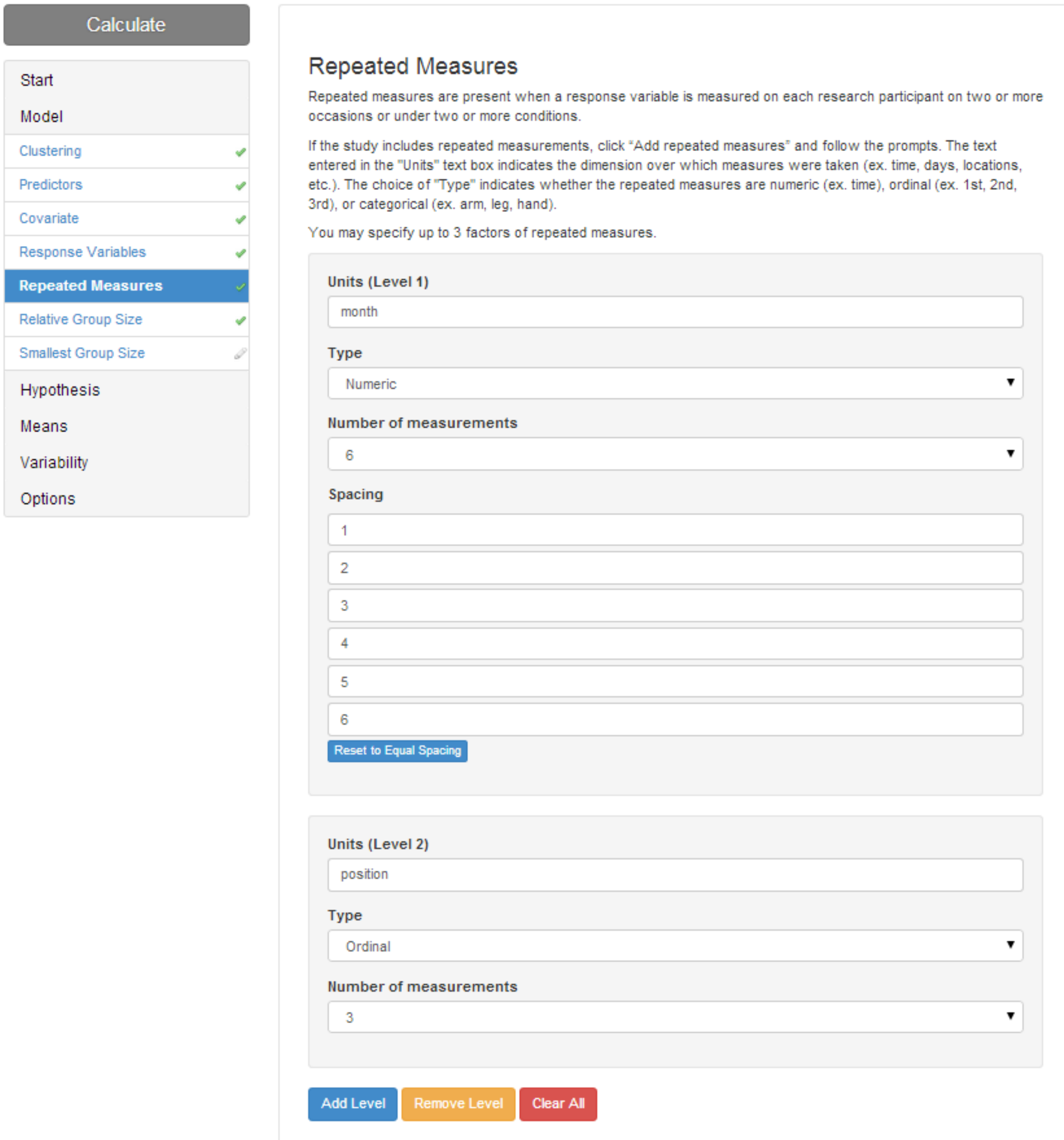


Figure 21: Repeated Measures: Add Level

3.2.7. Relative Group Sizes (if solving for Power)

For designs with multiple study groups (see Section 3.2.3), the user may specify equal or unequal group sizes. On the Relative Group Sizes screen, the user can select the relative sizes of each group by selecting a value from the drop down list.

For example, consider a design with males and females, randomized to receive either an active drug or a placebo. For equal group sizes, a "1" should be selected for each drop down list as shown in Figure 22. However, if there were twice as many males receiving the drug compared to females receiving the drug, the user would select a "2" for the male + drug group, and "1" for the remaining groups.

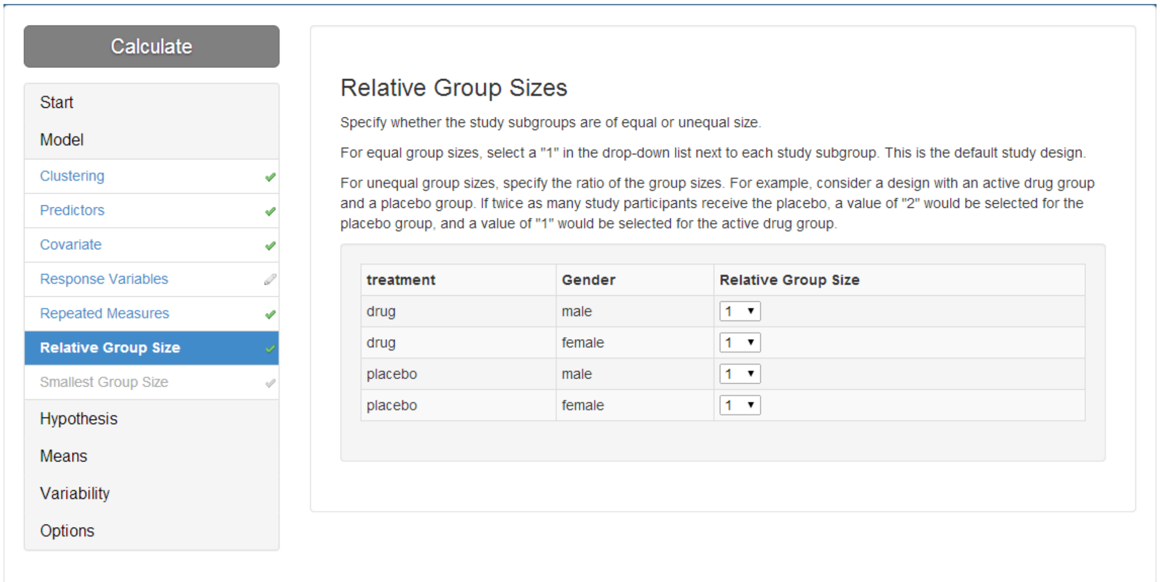


Figure 22: Relative Group Sizes Screen

3.2.8. *Smallest Group Size*

When solving for power, the user specifies the total sample size for the design by the relative group sizes and the smallest group size. On the *Smallest Group Size* screen, the user may enter one or more values describing the number of participants in the smallest group.

For example, consider a design with a treatment and a placebo group, in which three times as many participants receive the treatment compared to the placebo. With a smallest group size of 20, 30, or 40, the total sample size for the design would be 80 (i.e. 60 treated participants, 20 with placebo), 120, and 160 participants respectively.

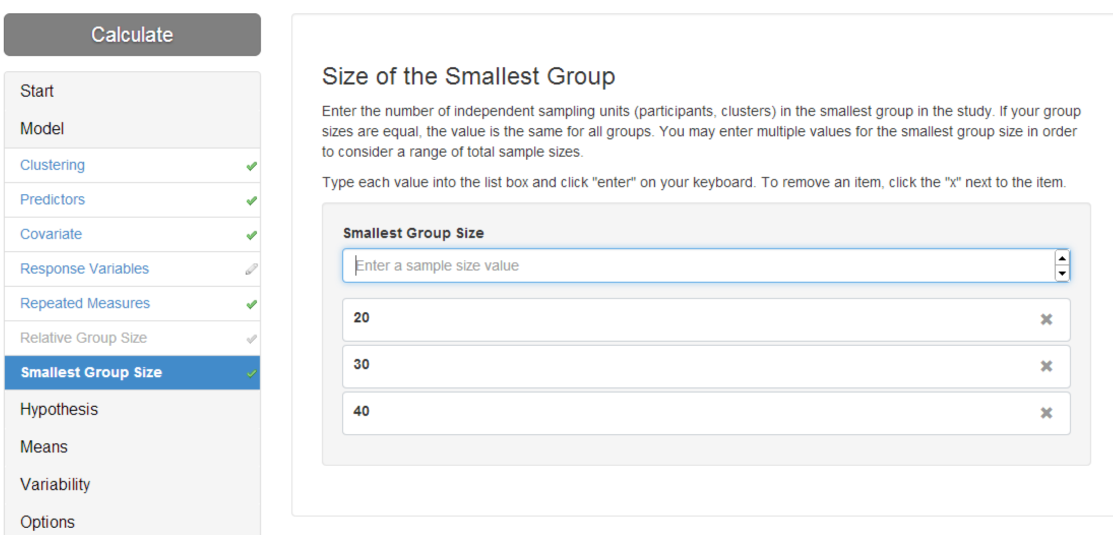


Figure 23: Smallest Group Size Screen

3.3. Hypothesis

3.3.1. Introduction

This screen provides an introduction to the *Hypothesis* section.

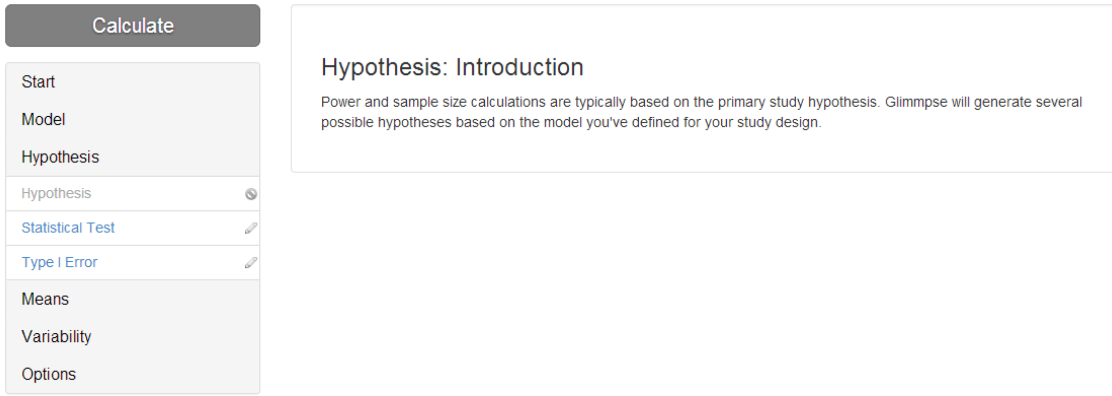


Figure 24: Hypothesis Introduction Screen

3.3.2. Hypothesis

The *Hypothesis* screen allows the user to select the primary hypothesis of interest. The user first selects the type of hypothesis by clicking the drop down list. Additional information will be requested depending on the type of hypothesis.

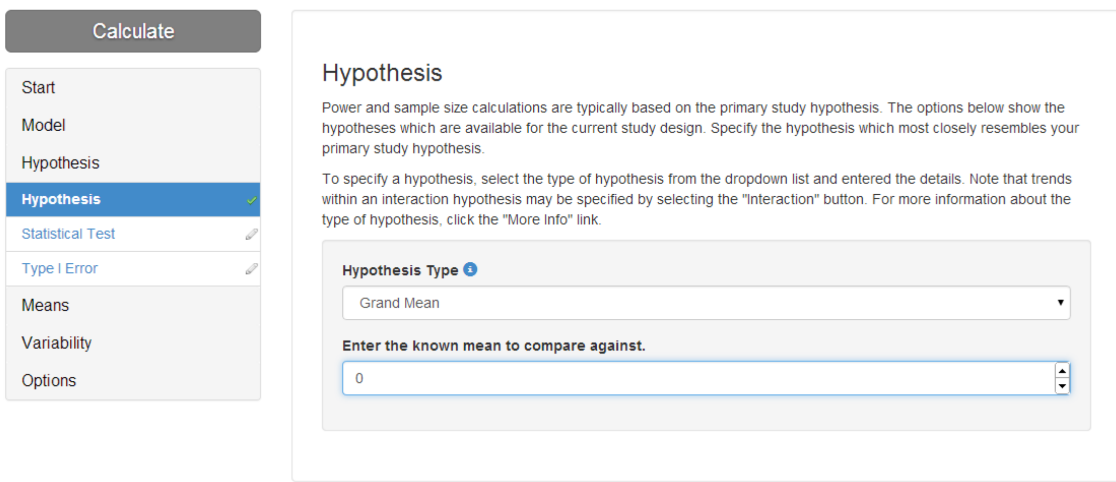


Figure 25: Hypothesis Screen

A *Grand Mean* hypothesis compares the overall mean response in a sample of participants against a known value. For example, an investigator may wish to determine if body mass index values for participants in a particular state differs from the United States national average. After selecting the *Grand mean* radio button, the user will be prompted to enter the known mean value for each response variable.

A *Main effect* hypothesis tests for the effect of a single predictor variable averaged across all other factors. For example, testing whether responses of participants in the treatment group differ on average from participant responses in a placebo group is a common main effect hypothesis. After selecting the *Main effect* radio button, the user will be prompted to select one predictor of interest by selecting the appropriate radio button.

A *Trend* hypothesis tests whether the effect of a single predictor follows a particular polynomial pattern, such as a linear or quadratic trend, across different levels of the predictor. After selecting the *Trend* radio button, the user will be prompted to select one predictor of interest. In addition, the user may select from six possible trends: no trend, change from baseline, linear trend, quadratic trend, cubic trend, or all polynomial trends.

An *Interaction* hypothesis tests whether the effect of one predictor changes depending on the value of one or more additional predictors. An interaction test also can be interpreted as a test of differences, as well as a test of parallel trajectories of response. For example, testing whether the effect of a cholesterol lowering medication on total serum cholesterol differs depending on the participant's gender is an example of an interaction hypothesis. After selecting the *Interaction* radio button, the user will be prompted to select one or more factors of interest by clicking the appropriate check boxes. In addition, the user may specify a trend for given factor by clicking the *Edit trend* button.

3.3.3. Statistical Test

The *Statistical Test* screen allows the user to select one or more statistical tests for the power or sample size calculations. A tutorial providing guidelines for selecting a test is available from the GLIMMPSE Tutorials page at `http://samplesizeshop.org/education/tutorials`. Select the statistical test(s) you wish to use by clicking one or more check boxes.

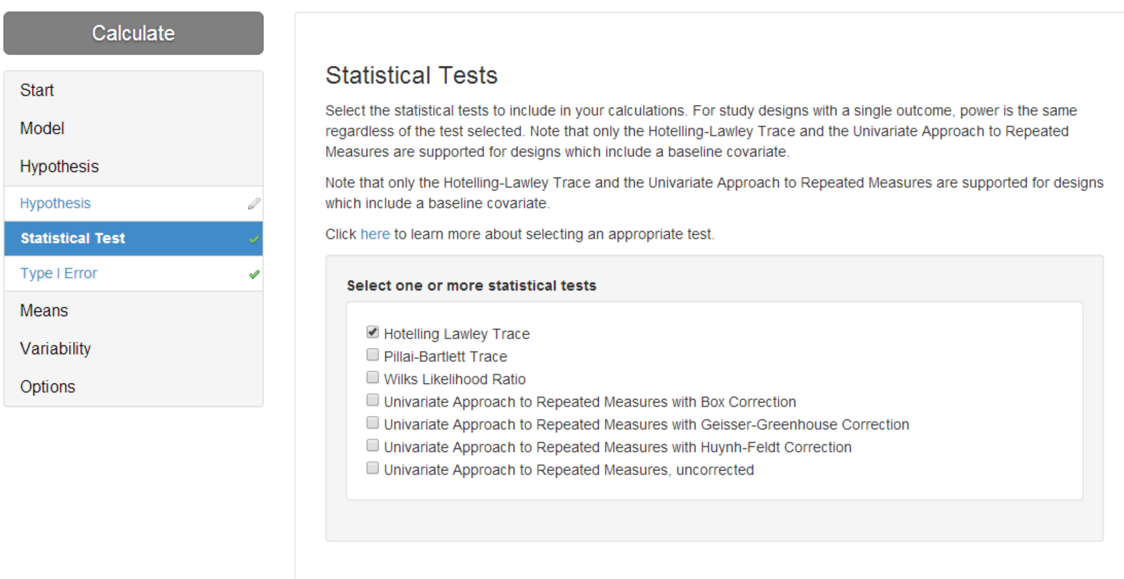


Figure 26: Statistical Tests

3.3.4. Type I Error

Enter the target values for Type I Error as decimals (i.e. 0.05) in the Type I Error Values box. The user may specify up to five Type I Error values.

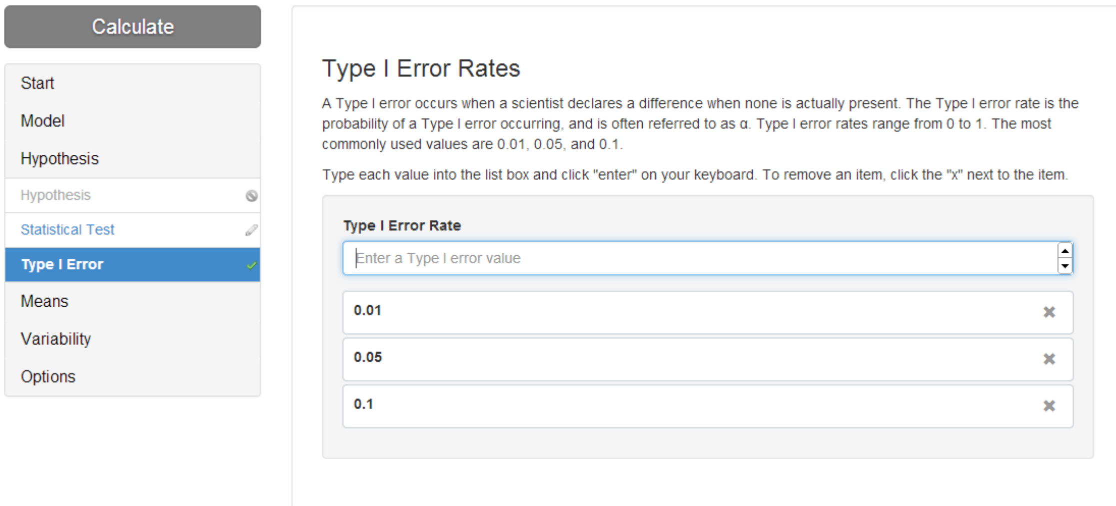


Figure 27: Type I Error

3.4. Means

3.4.1. Introduction

This screen provides an introduction to the *Means* section.

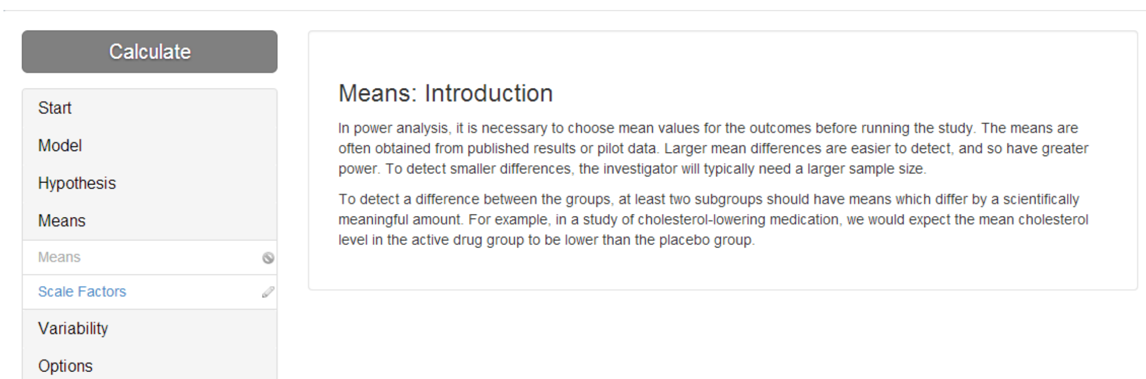


Figure 28: Means Introduction Screen

3.4.2. Means

The *Means* screen allows the user to enter the expected mean value for the experiment. Expected mean values are typically drawn from the literature or from pilot data. Differences between the entered means typically represent the smallest clinically relevant difference. The table should contain at least one value that is non-zero.

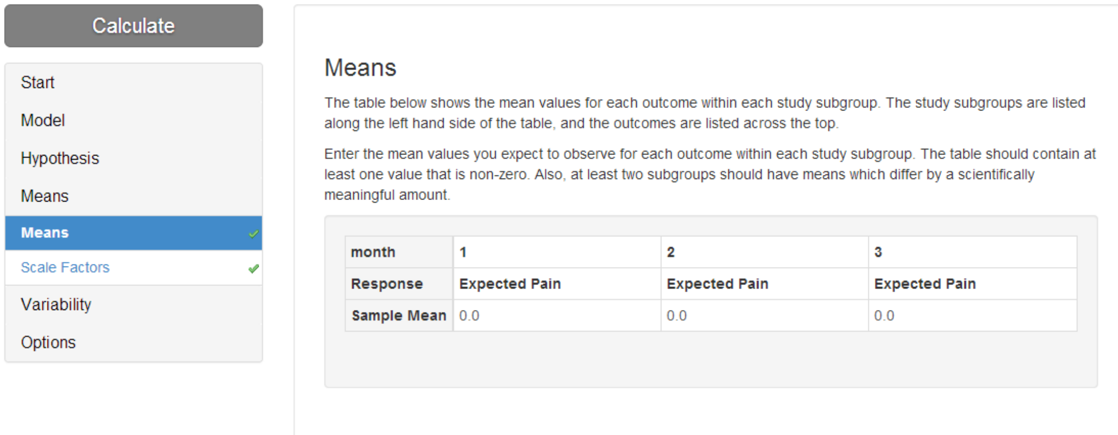


Figure 29: Means Screen

For designs with repeated measures, the user may enter means at each time (place, etc.).

3.4.3. Scale Factors

The *Scale Factors* screen for Means allows the user to compute power or sample size for the means as specified. For example, entering the scale factors 0.5, 1, and 2 would compute power for the the mean values divided by 2, the mean values as specified, and the mean values multiplied by 2. Type each value into the text box and press Enter on your keyboard. To remove an item, click the ✖ next to the item.

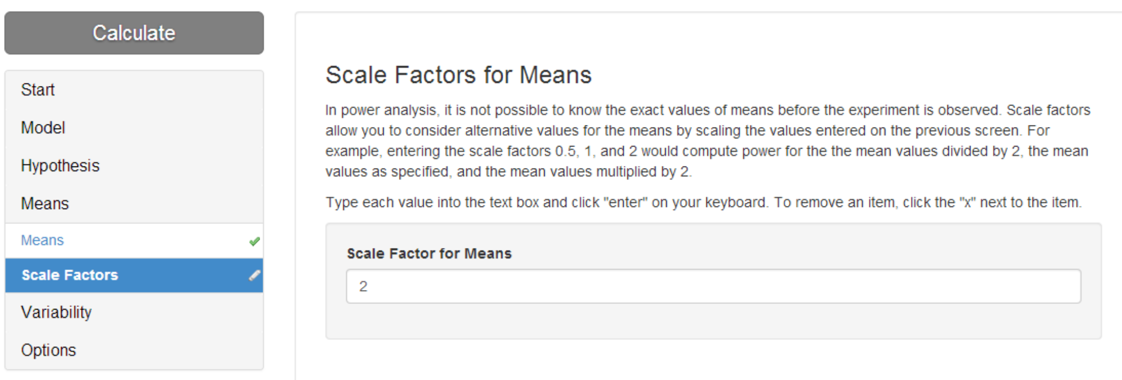


Figure 30: Scale Factors for Means Screen

3.5. Variability

3.5.1. Introduction

This screen provides an introduction to the *Variability* section.

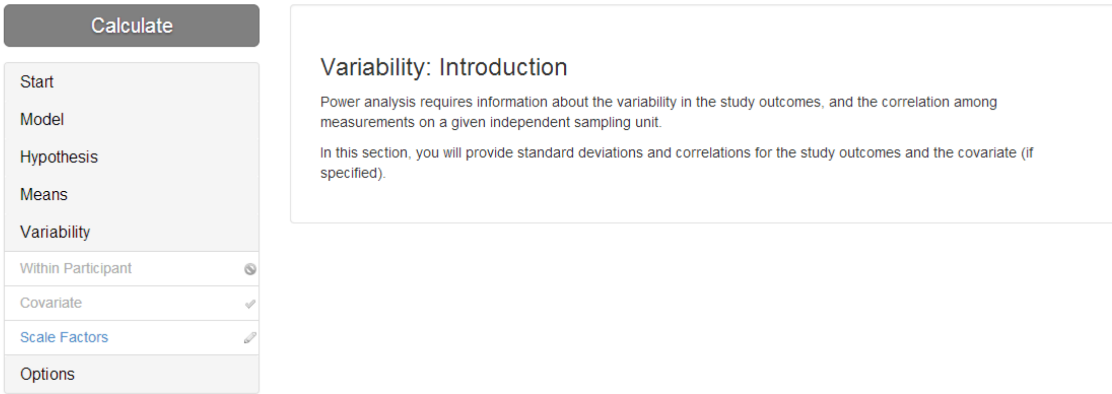


Figure 31: Variability Introduction Screen

3.5.2. Within Participant Variability

For a given participant, responses may vary across repeated measurements and for different response variables. The amount of variability can dramatically impact power and sample size. The *Within Participant Variability* screen allows the user to describe the variability he or she expects to observe for each within participant factor and response variable.

Separate tabs are presented for each "source" of correlation in the design. The *Responses* tab allows the user to specify the standard deviations of the response variables and any correlation between them. If repeated measures are present, a single tab will be presented for each level of repeated measures. Figure 32 shows an example design in which blood pressure is measured once a month for six months. GLIMMPSE will automatically combine the sources of correlation into a final covariance matrix.

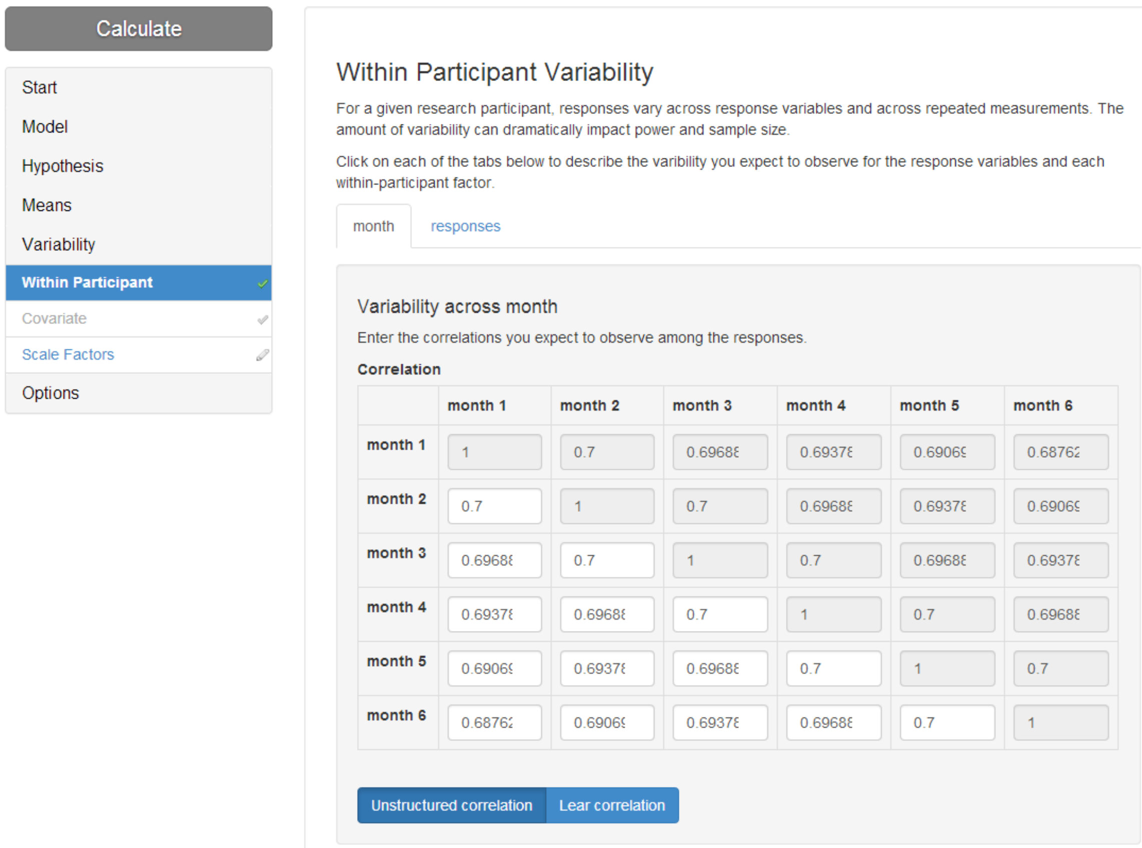


Figure 32: Within Participant Variability

3.5.3. Scale Factors

While GLIMMPSE requests standard deviations, it actually computes variances when it conducts the power or sample size calculations. There may be considerable uncertainty about what standard deviation or variance value to use. To account for this uncertainty, it is common to calculate power or sample size using alternative values for variability. Scale factors allow you to consider alternative values for variability by scaling the calculated covariance matrix. For example, entering the scale factors 0.5, 1, and 2 would compute power for the covariance matrix divided by 2, the covariance matrix as entered, and the covariance matrix multiplied by 2. Type each value into the text box and press Enter on your keyboard. To remove an item, click the ✖ next to the item.

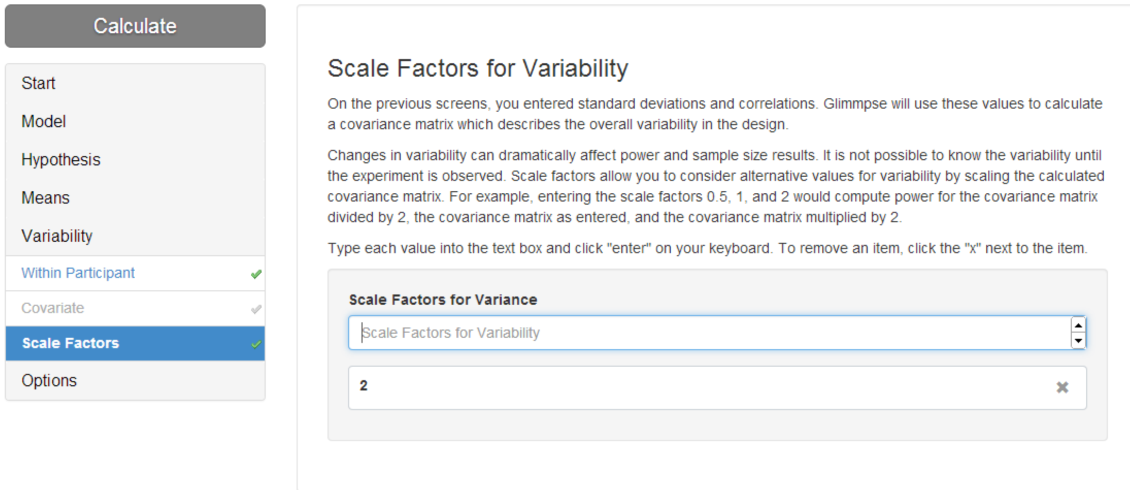


Figure 33: Scale Factors for Variability Screen

3.6. Options

This screen provides an introduction to the Options section.

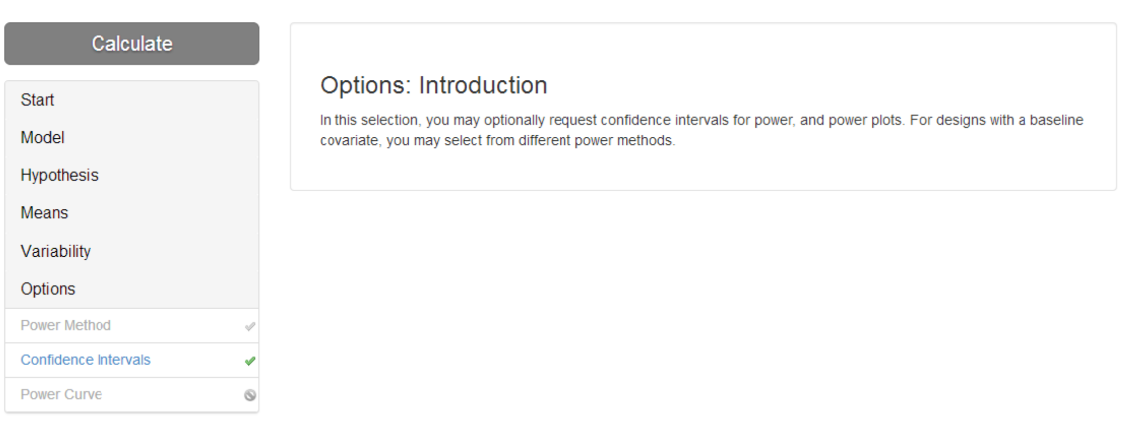


Figure 34: Options

3.6.1. Power Calculation Method

For designs with a baseline covariate, two different methods are available to calculate power: quantile and unconditional power. For theoretical details, please see Glueck and Muller (2003). Select the power methods by clicking the check boxes. If quantile power is selected, the user must also specify one or more quantile values. For example, median power would be obtained by selecting *Quantile* power and entering "0.5" in the quantile list box.

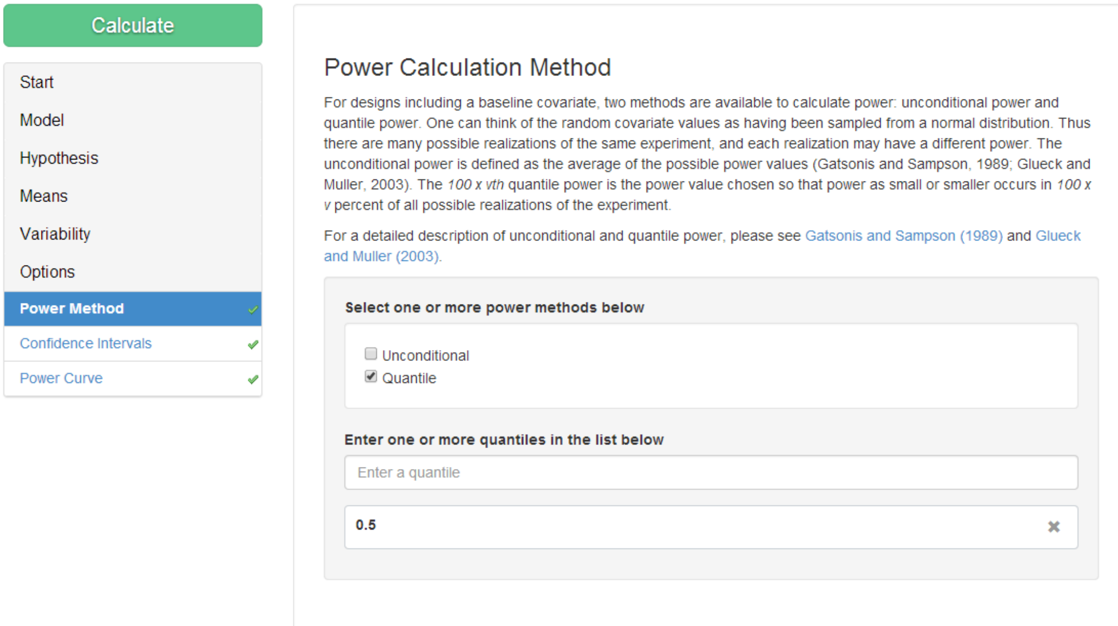


Figure 35: Statistical Tests

3.6.2. Confidence Intervals

Power analysis involves some uncertainty in the choices for means and variability. Therefore, the *Confidence Intervals* screen allows the user to request confidence intervals on the power results. To include confidence intervals, uncheck the checkbox. The information on the confidence interval screen describes the data set (or publication) from which the choices for means and variances were obtained. For example, if a scientist were calculating power based on the means and variances obtained from pilot data, the scientist would enter information describing the pilot data set. The following information is required:

The *Assumptions* section allows the user to indicate if he or she is uncertain about the variance, but reasonably certain of the mean values, or uncertain of both the means and variance.

The *Upper and lower tail probabilities* define the width of the confidence interval. For example, a centered 95% confidence interval would have both upper and lower tail probabilities of 0.025.

The *Total sample size* value indicates the number of independent sampling units in the pilot data set (or publication).

The *Rank of the design matrix* describes a property of the predictor matrix used in the pilot data set. Please see Muller and Stewart (2006) for details about matrix rank.

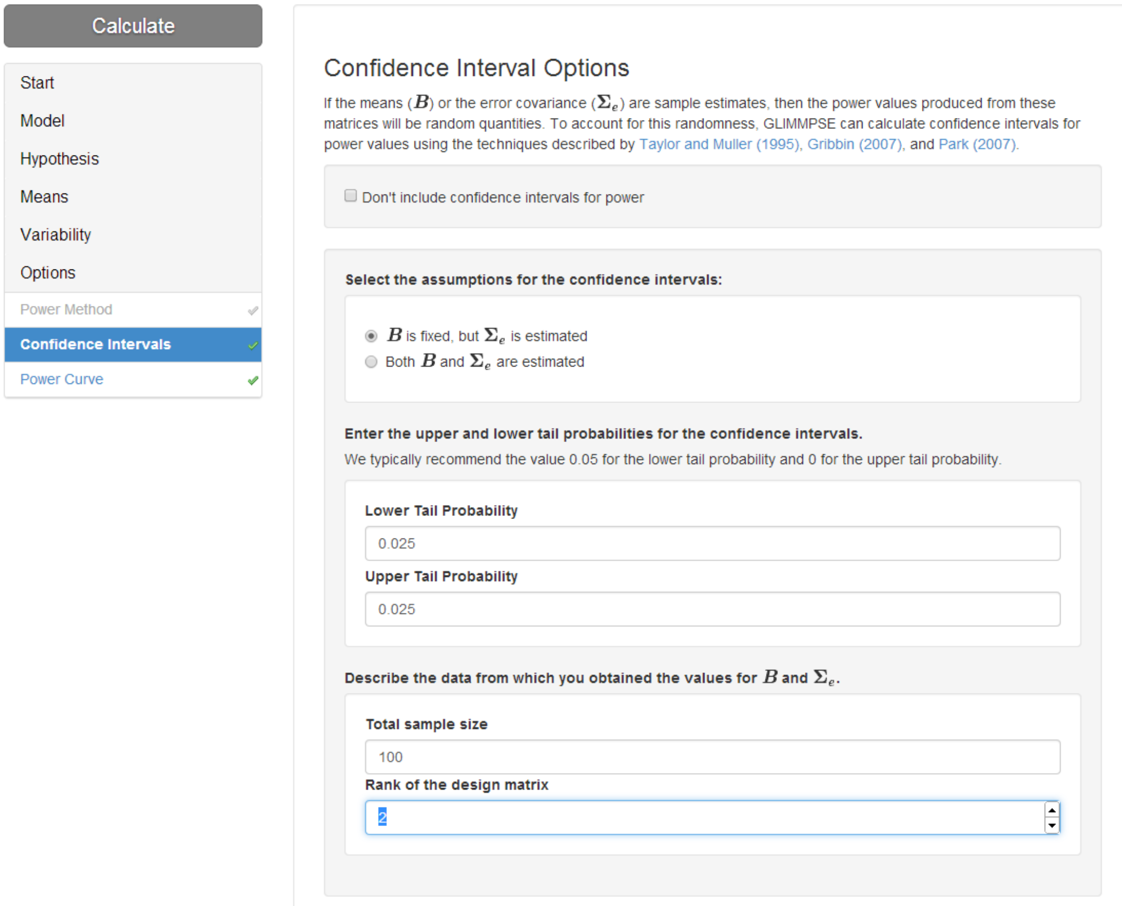


Figure 36: Confidence Intervals

3.6.3. Power Curve Options

The *Power Curve Options* screen allows the user to create a power curve. A power curve describes the change in power (Y axis of the power curve) relative to the total sample size, regression coefficient scale factor, or the variability scale factor (all options for the X axis of the power curve).

To create a power curve, the user must 1) uncheck the check box, 2) select the value to appear on the horizontal axis, and 3) add one or more data series.

Depending on the study design, the user may request a large number of power or sample size values in a single request. A data series is defined by selecting a subset of the power or sample size values. The user creates a data series by selecting values for several study design variables and clicking the checkbox. A data series will be displayed as a single line on the power curve plot, as shown in Figure .

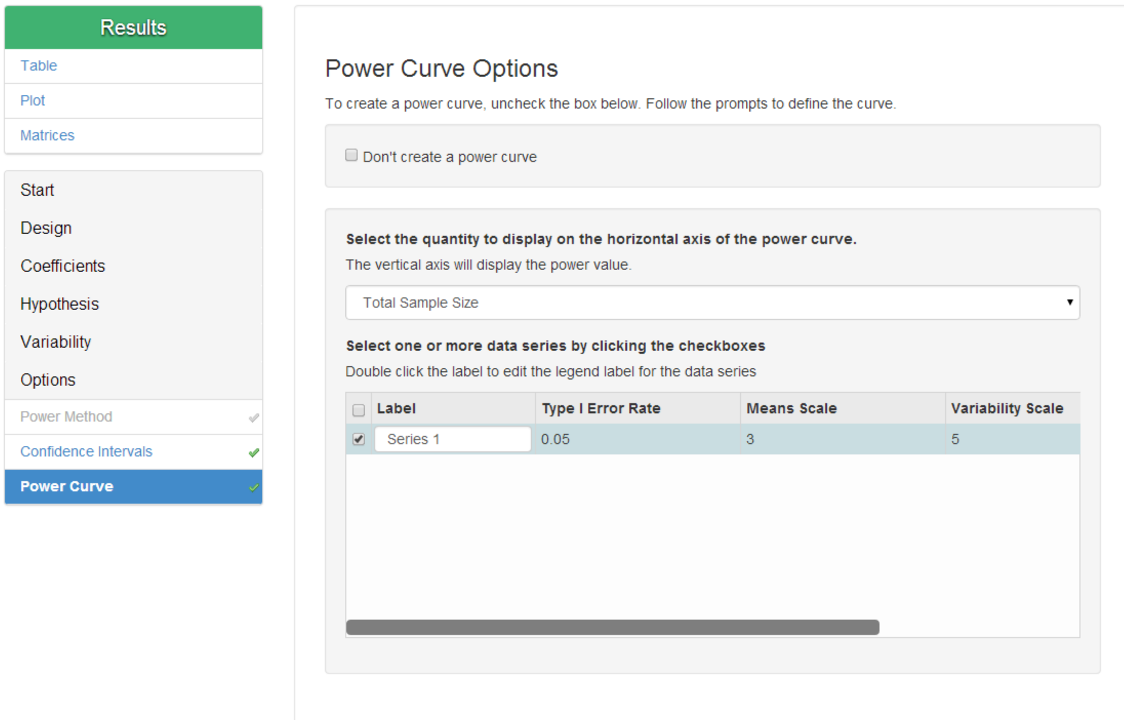


Figure 37: Power Curve

Note that the *Power Curve Options* screen is the final screen in the GLIMMPSE wizard. If the study design is not complete, the Calculate button will be disabled . If you click on the Calculate button while it is disabled, a modal will appear on the screen and list the missing inputs, as shown in Figure 38.

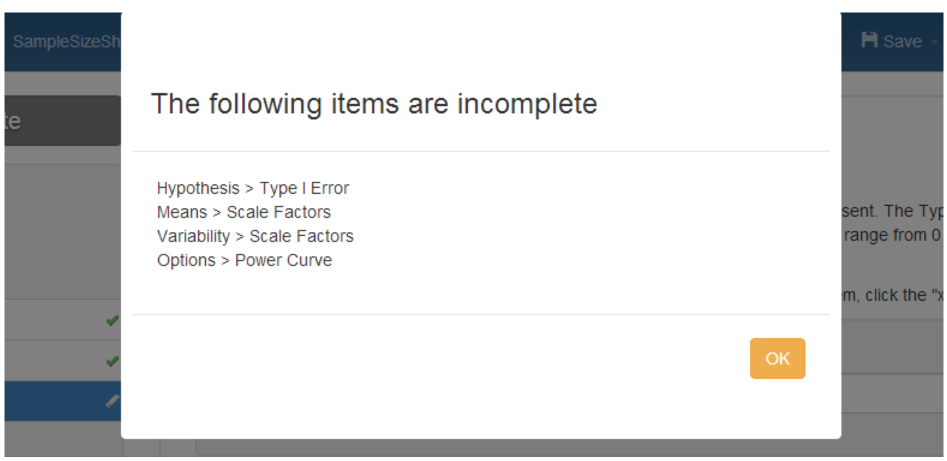


Figure 38: Incomplete Study Design Modal

3.7. Calculate

When sufficient information for your power or sample size calculation has been entered, the *Calculate* button will be highlighted green. Click to receive the results of your power analysis. Example results are shown in

Figures 39 and 41. For detailed information regarding the Power Results table, refer to Table 1. When calculating sample size for a clustered design, Power Results provide total sample size, with a breakdown of sample size per unit, as shown in Figure 40.

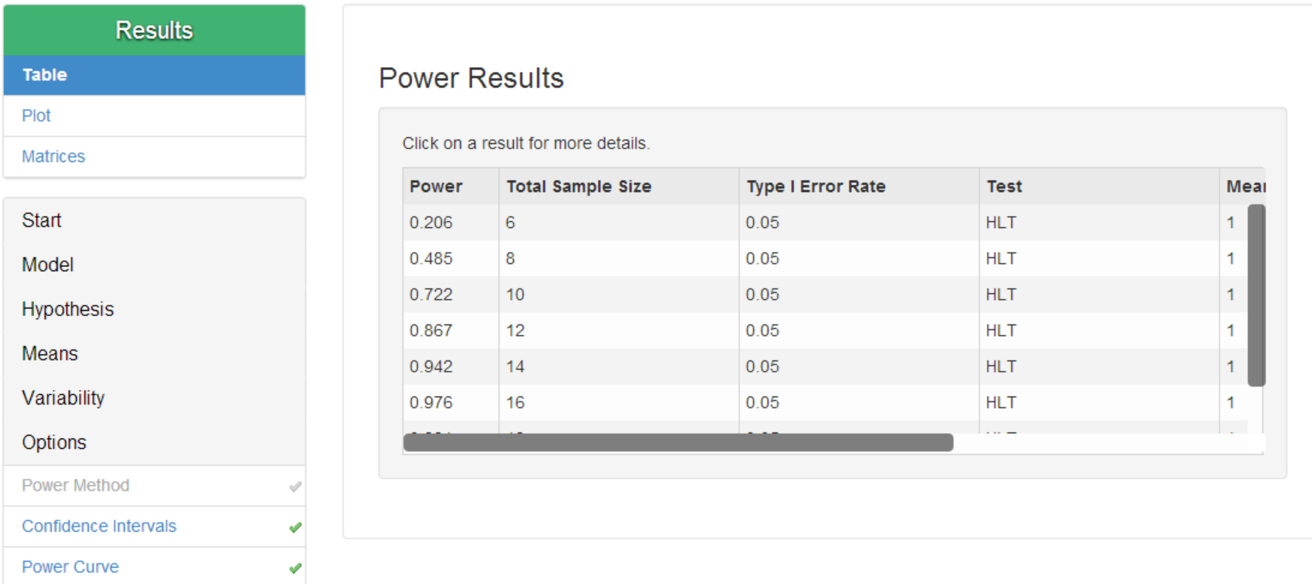


Figure 39: Results Table

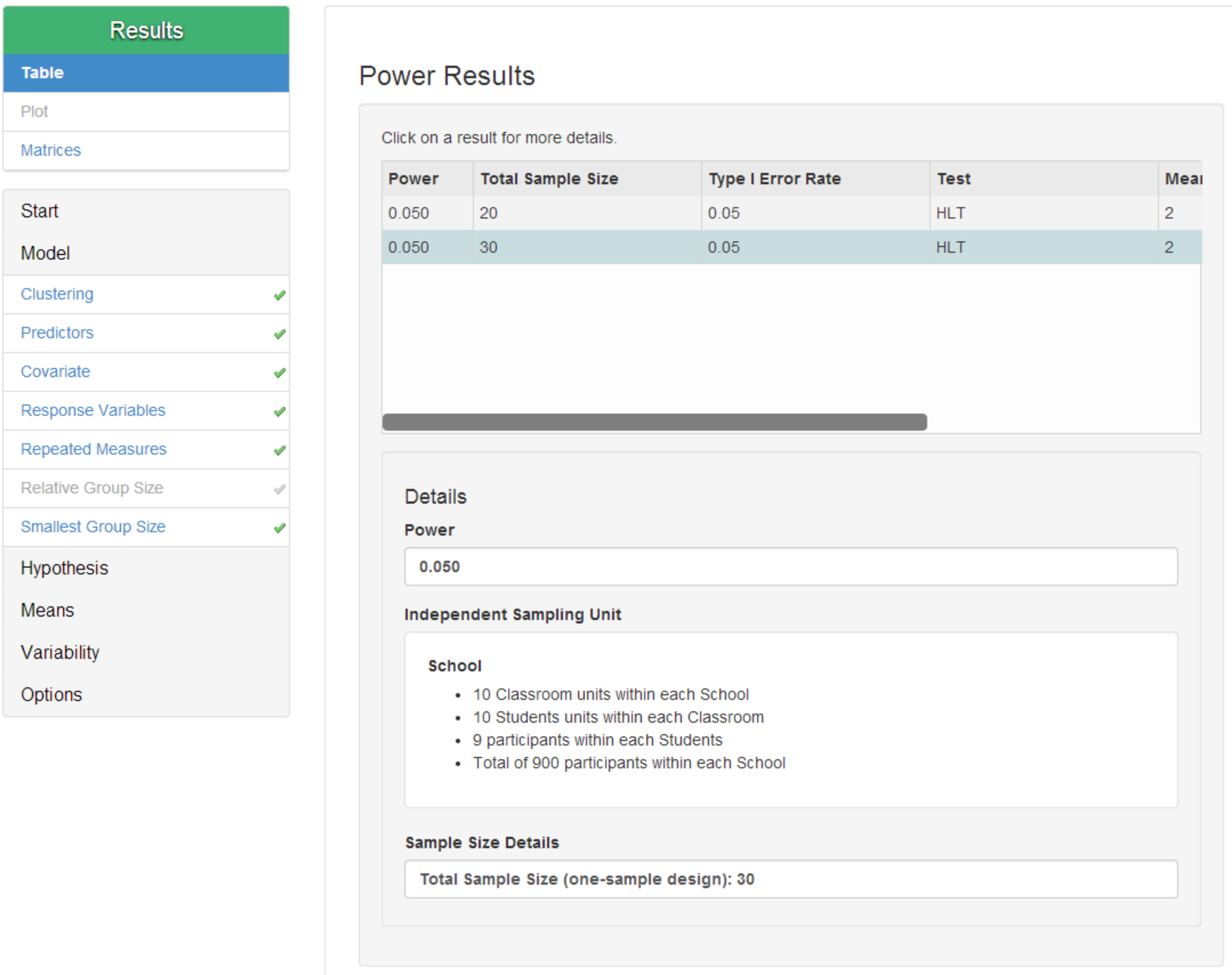


Figure 40: Total Sample Size for Clustered Design

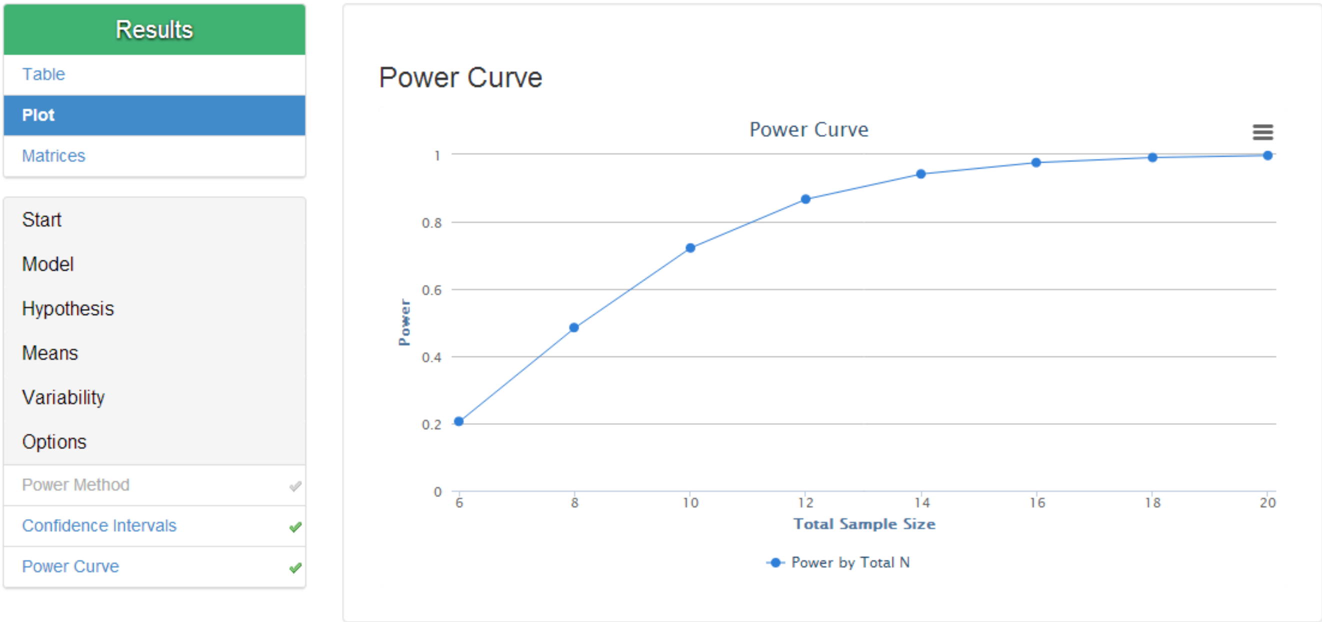


Figure 41: Results Plot

4. *Matrix Mode* Screen-by-Screen Tour

Matrix Mode allows direct input of all matrices required for a power calculation. In *Matrix Mode* users receive less guidance than in *Guided Mode*, and are assumed to possess in-depth statistical training.

4.1. Start

4.1.1. Introduction

The *Introduction* screen shown in Figure 42 briefly describes the required matrix inputs for the power or sample size calculation.

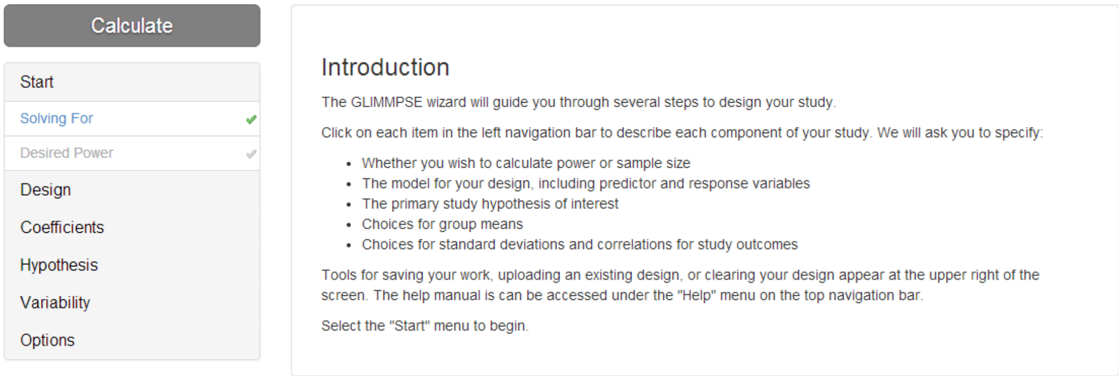


Figure 42: Introduction Screen for *Matrix Mode*

4.1.2. Solving For?

The *Solving For?* screen shown in Figure 43 allows the user to select either a power or sample size calculation.

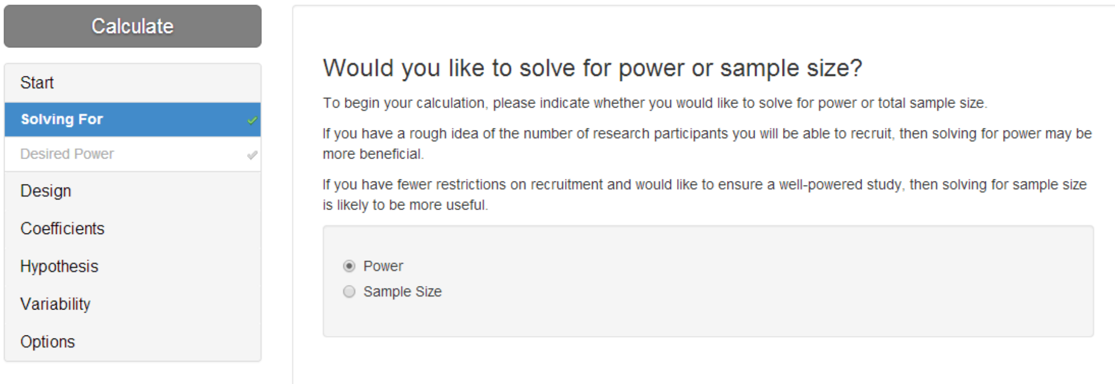


Figure 43: Solving For? Screen

When *Power* is selected, the inputs will be used for a power analysis. The power analysis will produce a value(s) between 0 and 1, representing the probability the study will answer the question of interest. When *Total Sample Size* is selected, the inputs will be used to calculate the number of individual sampling units (also called participants, if referring specifically to people) needed for the study to achieve the desired power.

If the number of participants is not set, we recommend solving for sample size in order to obtain the appropriate sample size for achieving the goals of your study. However, if sample size is set due to budgetary or other restrictions, a power calculation will indicate the probability that the study will provide a definitive answer to the question of interest.

On the screen, select *Power* or *Total Sample Size* by selecting the appropriate radio button.

4.1.3. Desired Power (if solving for Total Sample Size)

When solving for sample size, the user must enter the desired power for the study. Enter the target values as decimals (i.e. 0.95) in the Power Values box shown in Figure 44 and press Enter on your keyboard to add the value to the list.

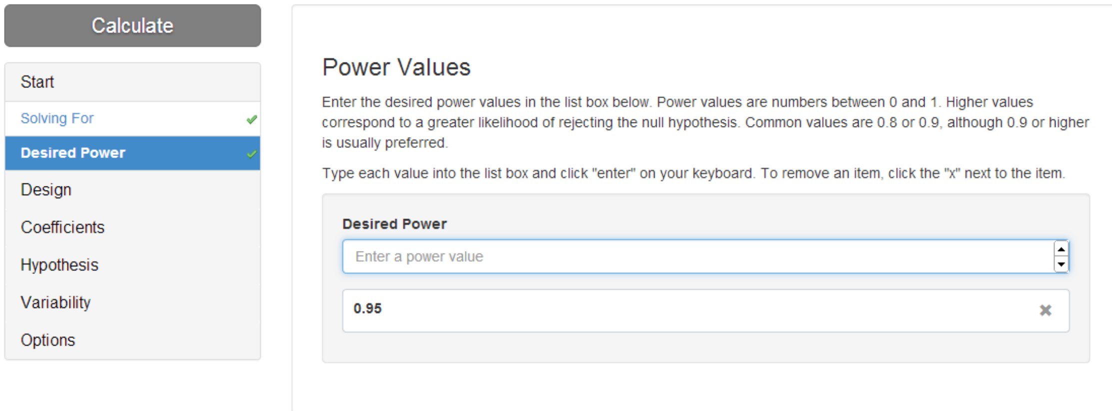


Figure 44: Desired Power Screen

4.2. Design

4.2.1. Design Essence

In the *Design* section, the user will define the composition of the study by specifying the number of groups, how subjects are divided into groups, the size of each group, and whether the design will include a Gaussian covariate.

The Design Essence Matrix

In the general linear multivariate model with fixed predictors, $\boldsymbol{Y} = \boldsymbol{XB} + \boldsymbol{E}$, the $\boldsymbol{X}$ matrix represents the study design. The same is true for $\boldsymbol{F}$ in the general linear multivariate model with fixed predictors and a Gaussian predictor (Glueck and Muller 2003). For simplicity, we will only discuss $\boldsymbol{X}$ (since the instructions do not change for $\boldsymbol{F}$). In data analysis, the $\boldsymbol{X}$ matrix would contain a single row for each subject. Since power analysis does not include actual data, the design "essence" matrix (Muller and Stewart 2006) is a version of the $\boldsymbol{X}$ matrix that contains a single row for each unique combination of predictors in the study design. Note that the essence matrix specifies only the fixed, or categorical, predictors in the study design.

For example, consider a 2-factor ANOVA design with 2 levels per factor, 3 subjects per group, and a cell means coding. In data analysis, the design matrix and corresponding essence matrix would be:

$$\boldsymbol{X} = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{bmatrix} \Longrightarrow \mathrm{Es}\left(\boldsymbol{X}\right) = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix}$$

GLIMMPSE requires that the design coding is full rank. Unequal group sizes may be coded by replicating a row to reflect the relative sizes of the groups.

After entering the desired dimensions for the matrix in the row and column dimension text boxes, click anywhere on the screen for the matrix to be resized. Type in the matrix text boxes shown in Figure 45 to enter the matrix information.

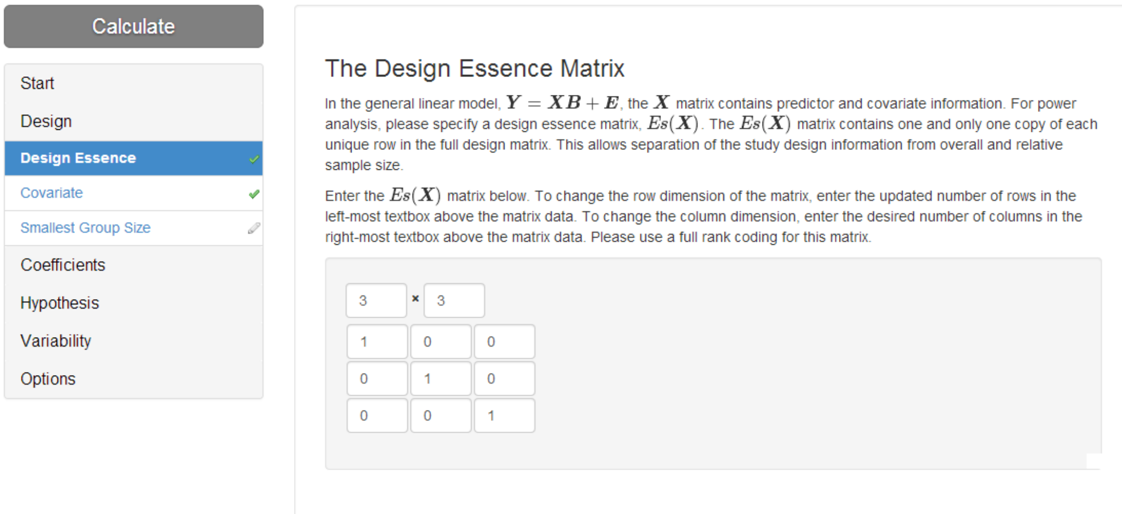


Figure 45: Type I Error

4.2.2. Covariate

Currently, GLIMMPSE only performs power calculations for hypotheses about fixed predictor variables. However, a single, continuous, normally distributed predictor variable may be included in the analysis.

To include such a predictor, click the checkbox next to *Control for a single, normally distributed Gaussian predictor* at the bottom of the screen, shown in Figure 46.

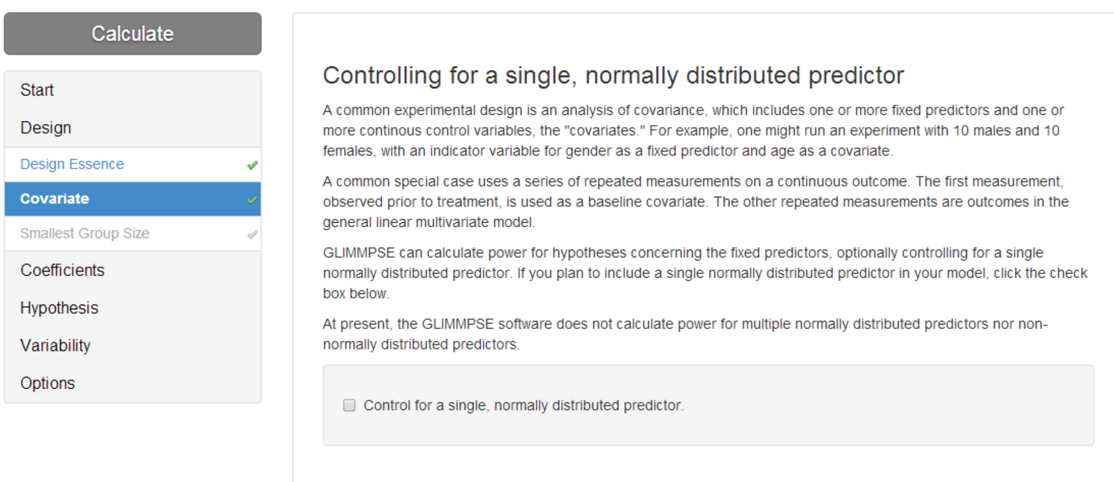


Figure 46: Gaussian Predictor Screen

4.2.3. Smallest Group Size

When solving for power, the user specifies the total sample size for the design by the relative number of repeated rows in the design essence matrix, and the smallest group size. On the *Smallest Group Size* screen, the user may enter one or more values describing the number of participants in the smallest group.

To enter one or more per group sample size, type the sample size in the *Per Group Sample Size* box, shown in Figure 47. After each entry, press Enter on your keyboard. To delete a value, select the unwanted value and click ✖ to remove the value from the list.

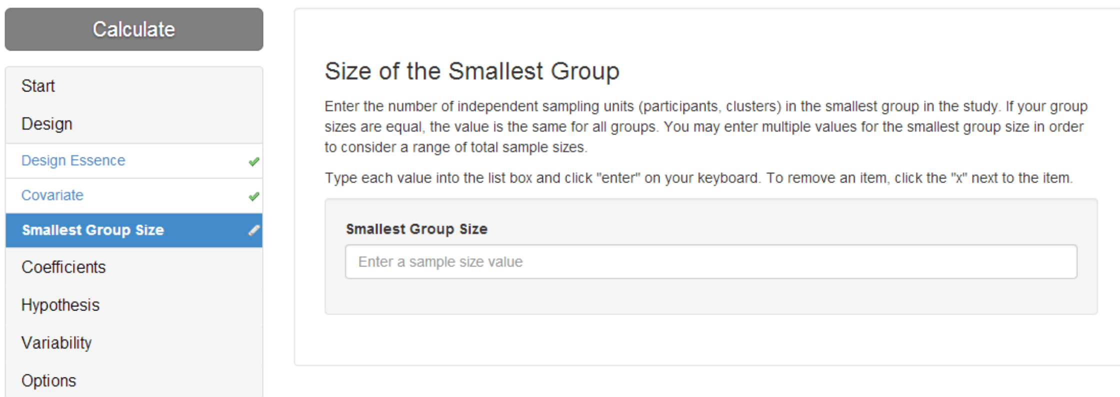


Figure 47: Smallest Group Size Screen

4.3. Coefficients

4.3.1. Beta Coefficients: B Matrix

This section requires the user to enter choices for values for the hypothesis test, $\boldsymbol{\Theta} = \boldsymbol{CBU}$.

In the general linear multivariate model with fixed predictors, $\boldsymbol{Y} = \boldsymbol{XB} + \boldsymbol{E}$, the $\boldsymbol{B}$ matrix represents the proposed relationship between the predictor variables, $\boldsymbol{X}$, and the outcome variables, $\boldsymbol{Y}$. The same is true for $\boldsymbol{B}_F$ in the General Linear Multivariate Model with Fixed Predictors and a Gaussian Predictor. For simplicity, we will only discuss $\boldsymbol{B}$ (since the instructions do not change for $\boldsymbol{B}_F$). To calculate power, enter values for the regression coefficients for each unique combination of predictors in the study design. The row dimension of $\boldsymbol{B}$ is determined by the number of columns in the essence matrix. Change the column dimension of $\boldsymbol{B}$ to match the intended number of outcomes in the study, or the columns of $\boldsymbol{Y}$ in the general linear multivariate model with fixed predictors regression equation.

For example, an investigator may want to compare vitamin D and calcium levels of children who live in three different regions: urban, suburban, and rural. The $\boldsymbol{B}$ matrix would have three pre-specified rows, one for each region, and two columns, one for vitamin D and one for calcium. To calculate power, the investigator must enter the expected mean vitamin D (column 1) and calcium (column 2) levels of the children in the rural (row 1), suburban (row 2), and urban (row 3) regions. The investigator may choose $\boldsymbol{B} = \begin{bmatrix} 120 & 4 \\ 60 & 8 \\ 45 & 10 \end{bmatrix}$ as shown below:

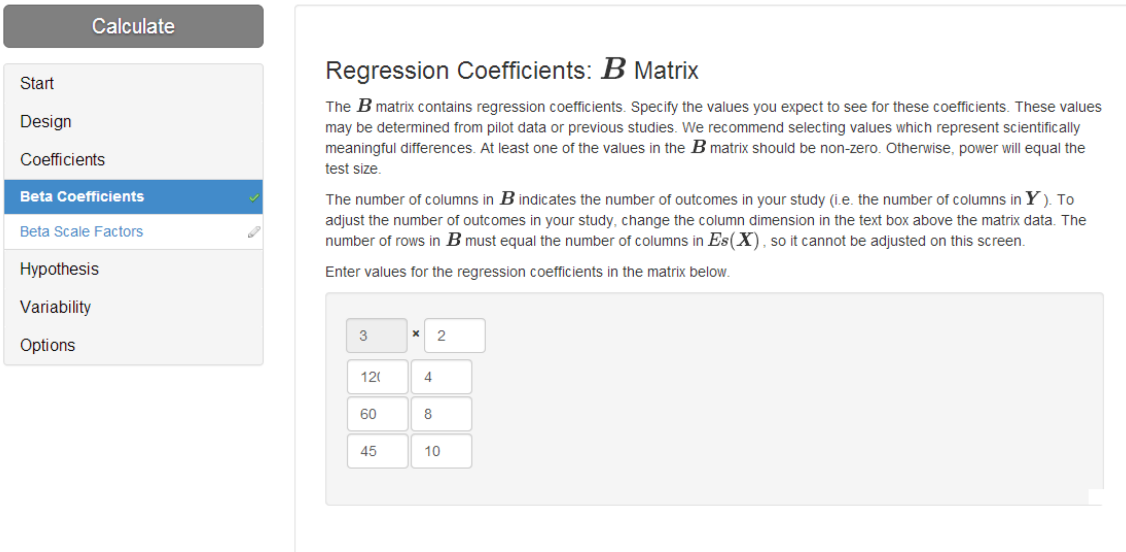


Figure 48: Beta Matrix

Enter the number of columns, or the number of outcomes in the study, in the column text box (right) in the matrix, as shown in Figure 48. Enter proposed values of the $\boldsymbol{B}$ coefficients in their corresponding text boxes in the matrix.

4.3.2. Beta Scale Factors

GLIMMPSE allows users to specify scale factors for the $\boldsymbol{B}$ matrix in order to generate power or sample size values for different coefficient values. Since power is based on proposed regression coefficients, it is common to calculate power for the proposed value, as well as alternative values such as half and twice the proposed value.

One or more scale factors for the $\boldsymbol{B}$ matrix may be specified for inclusion in the power calculation. For example, to calculate power for regression coefficients that are half the values in your $\boldsymbol{B}$ matrix, enter 0.5. To use the exact $\boldsymbol{B}$ matrix specified, enter 1. To delete a value, select the unwanted value and click ✖ to remove the value from the list, as shown in Figure 49.

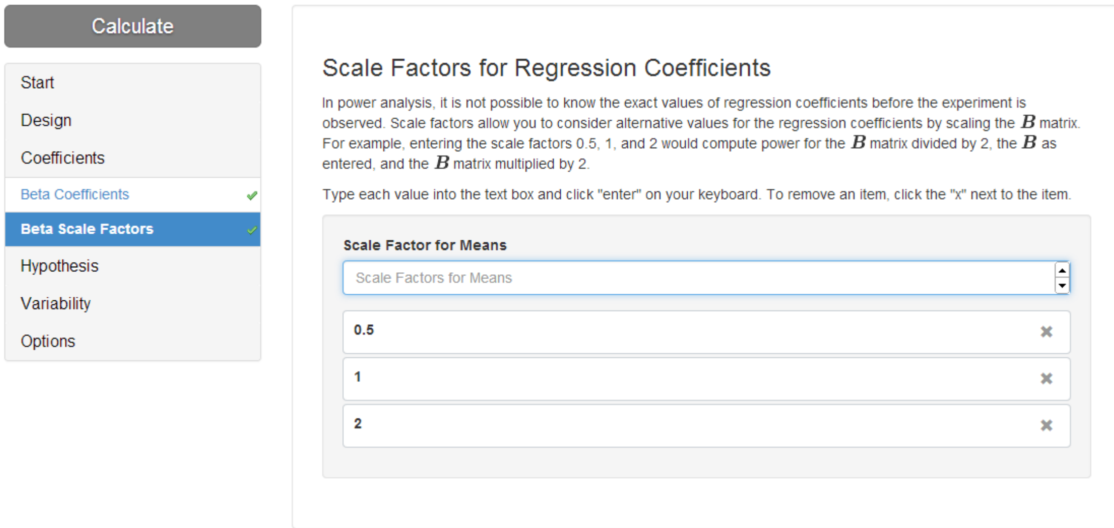


Figure 49: Beta Scale Factors

4.4. Hypothesis

In this section, the user defines the contrast matrices in the study. The contrast matrices, $\boldsymbol{C}$ and $\boldsymbol{U}$, consist of the hypotheses to be tested. They are used to calculate the expected hypothesis matrix, $\boldsymbol{\Theta} = \boldsymbol{CBU}$.

4.4.1. Between-Participant Contrast

The $\boldsymbol{C}$ matrix consists of the between-participant contrasts. The between-participant contrasts test hypotheses between independent sampling units. The number of rows in the $\boldsymbol{C}$ matrix represent the degrees of freedom for the hypothesis test. For example, suppose an investigator wants to compare the average final exam test scores of students in class A and class B. The contrast matrix would be $\boldsymbol{C} = \begin{bmatrix}1 & -1\end{bmatrix}$. When multiplied by $\boldsymbol{B}$, this becomes the difference in the proposed average test scores between class A and class B.

Enter the number of rows/number of contrasts in the study, in the row text box (left) under $\boldsymbol{C}$ Matrix to resize the blank matrix. Fill in the contrasts you wish to test in the matrix, as shown in Figure 50.

The number of rows in the $\boldsymbol{C}$ matrix cannot exceed the number of rows in the essence matrix minus 1. In addition, the $\boldsymbol{C}$ matrix must conform to the $\boldsymbol{B}$ matrix, so the number of columns cannot be adjusted on this screen.

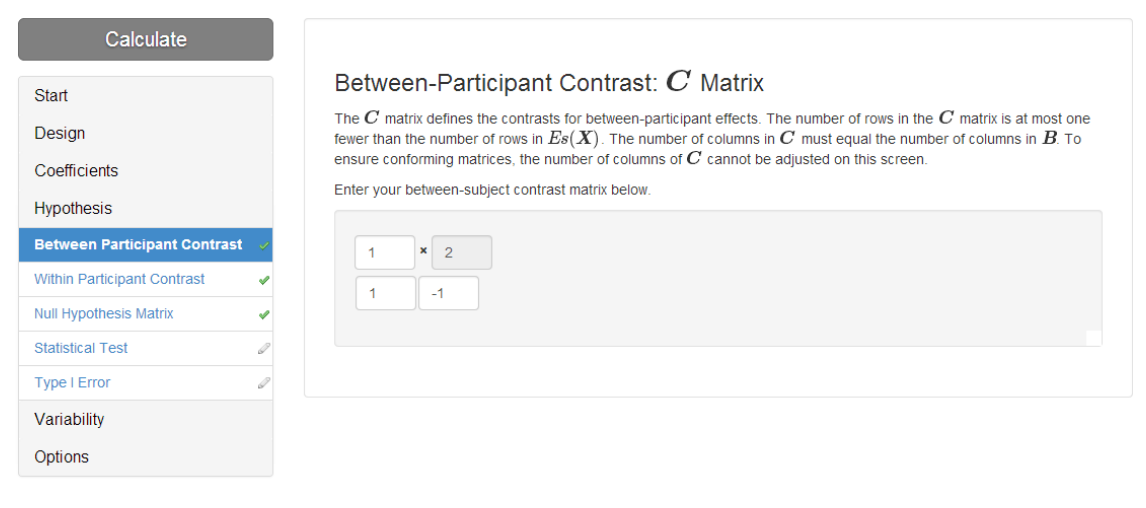


Figure 50: Between-participant Contrast Matrix

4.4.2. Within-Participant Contrast

The $\boldsymbol{U}$ matrix consists of the within-participants contrasts. The within-participants contrasts are the hypotheses that compare measurements on the same independent sampling unit.

The $\boldsymbol{U}$ matrix is most useful for multivariate designs and repeated measures. For example, suppose an investigator wants to examine whether student test scores improve from their midterm exams to their final exams. The investigator would have two measurements per student, one for the midterm and one for the final. The within-participant contrast matrix would be $\boldsymbol{U} = \begin{bmatrix} 1 & -1 \end{bmatrix}$. The matrix contrasts two different test scores, the midterm and the final, for the same student.

Enter the number of columns, or the number of within-subject contrasts, in the study, in the column text box (right). Fill in the contrasts in the matrix, as shown in Figure 51.

The $\boldsymbol{U}$ matrix must conform to the $\boldsymbol{B}$ matrix, so the number of rows cannot be adjusted on this screen.

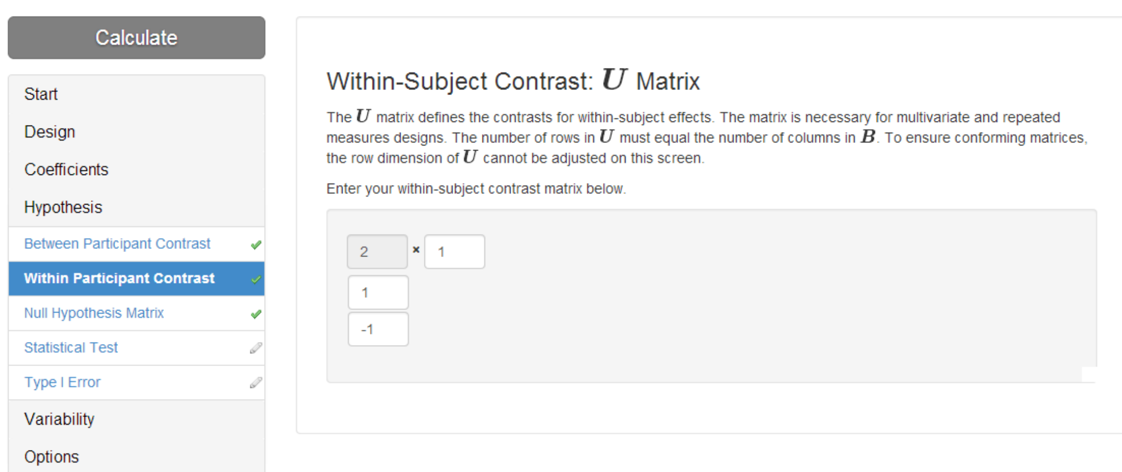


Figure 51: Within-participant Contrast Matrix

4.4.3. Null Hypothesis

The null hypothesis matrix, $\boldsymbol{\Theta}_0$, represents the test values the user expects to observe when the null hypothesis is true. When performing a power analysis, the values for the hypothesis tests are calculated as $\boldsymbol{\Theta} = \boldsymbol{CBU}$, and then compared against $\boldsymbol{\Theta}_0$. Commonly, $\boldsymbol{\Theta}_0$ is a matrix of zeroes.

For example, suppose an investigator wants to compare resting metabolic rate between subjects with HIV lipoatrophy, subjects with HIV only, and healthy controls. The null hypothesis of no difference between the three groups is $\boldsymbol{\Theta}_0 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$, appearing as shown in Figure 52.

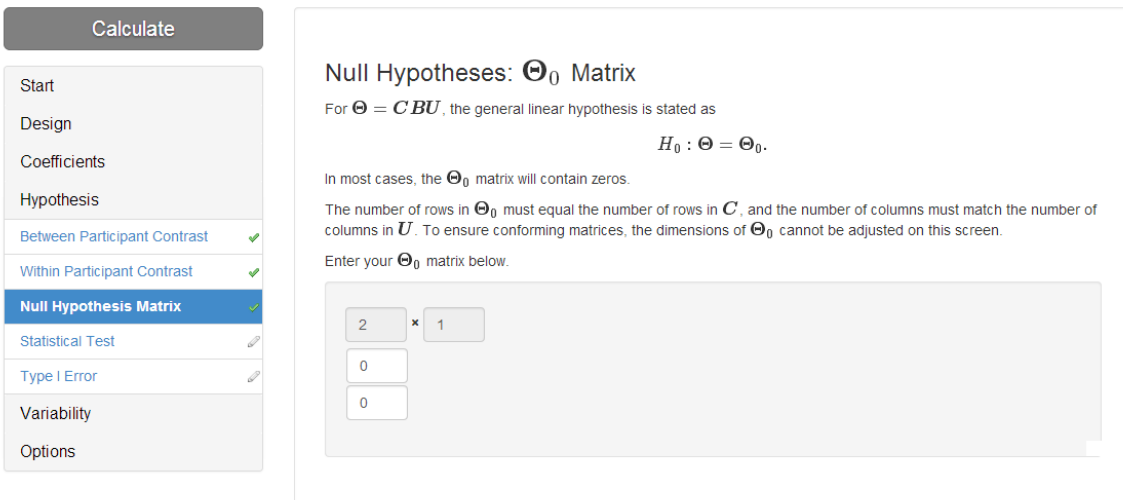


Figure 52: Null Hypothesis Matrix

Sometimes, however, the null hypothesis is based on previous studies or clinical experience. For example, suppose an investigator wants to compare foal birth weight between dams who are given feed formula A, feed formula B, and standard feed. In order to be cost effective, the new feed formulas must improve foal birth weight by more than 7 kg. The null hypothesis, then is $\boldsymbol{\Theta}_0 = \begin{bmatrix} 7 \\ 7 \end{bmatrix}$, appearing as shown in Figure 53.

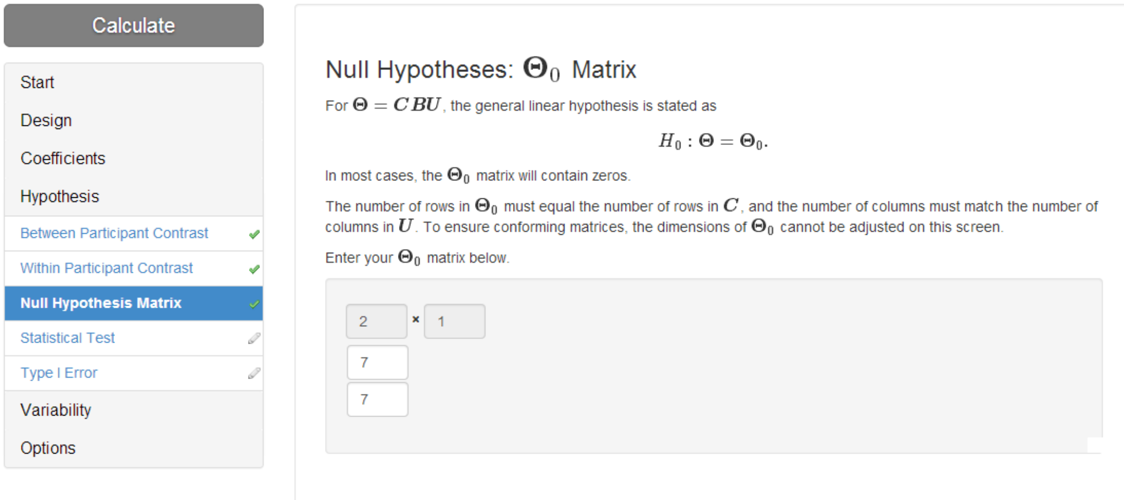


Figure 53: Non-zero Null Hypothesis Matrix

Θ_0 has the same number of rows as $\boldsymbol{C}$, and the same number of columns as $\boldsymbol{U}$. Therefore, its size cannot be adjusted on this screen. The user need only enter the matrix cell values.

4.4.4. Statistical Tests

The *Statistical Tests* screen allows the user to select one or more statistical tests for the power or sample size calculations. A tutorial providing guidelines for selecting a test is available from the GLIMMPSE Tutorials page at `http://samplesizeshop.org/education/tutorials`. Full theoretical details are available in Muller and Stewart (2006). Select the statistical test(s) by clicking one or more check boxes. For designs with a Gaussian covariate, only the Hotelling-Lawley trace and the Univariate Approach to Repeated Measures are valid.

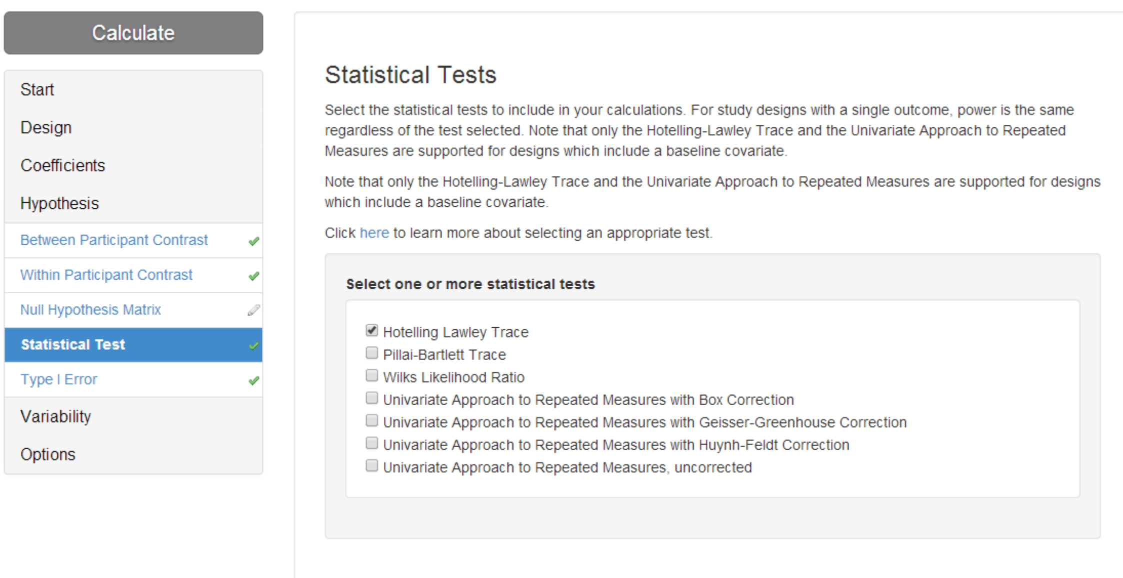


Figure 54: Statistical Tests

4.4.5. Type I Error

Enter the target values for Type I Error as decimals (i.e. 0.05) in the Type I Error Values box. The user may specify up to five Type I Error values.

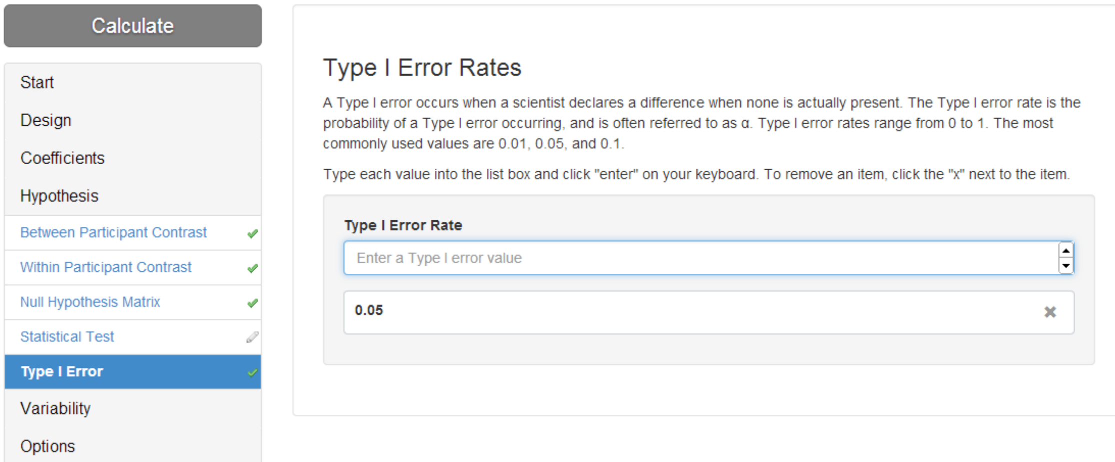


Figure 55: Type I Error

4.5. Variability

Variability describes how much measurements differ from each other. In this section, the user defines the covariance of errors and covariance related to the Gaussian covariate.

4.5.1. Error Covariance

For each independent sampling unit, $\boldsymbol{\Sigma}_e$ is the covariance of the random errors conditional on the values of the fixed predictors. The *Error Covariance* screen allows the user to define $\boldsymbol{\Sigma}_e$ by directly entering the covariance matrix values, as shown in Figure 56. To ensure conformance with the $\boldsymbol{B}$ and $\boldsymbol{U}$ matrices, the dimensions of the $\boldsymbol{\Sigma}_e$ matrix cannot be modifed on this screen.

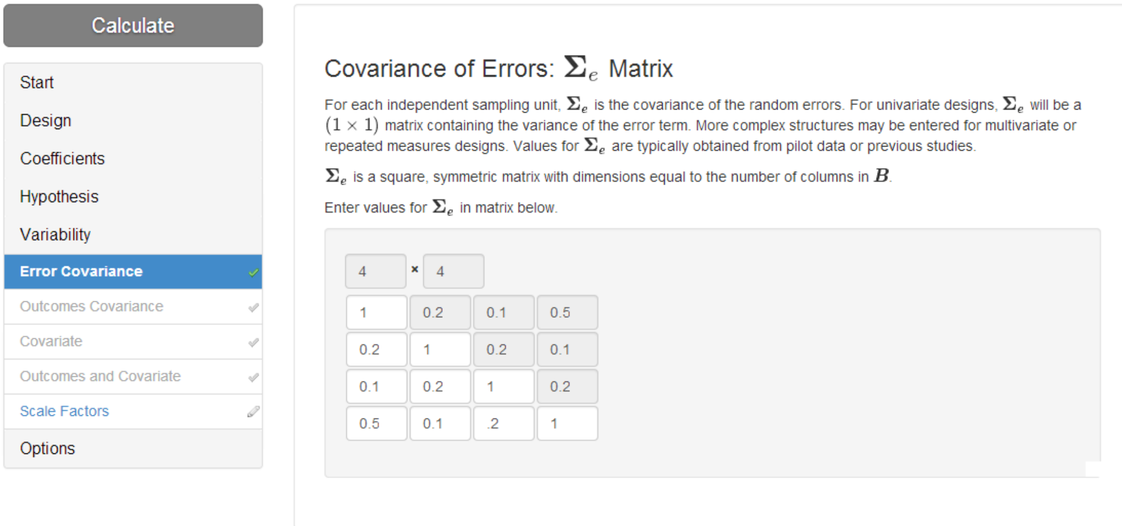


Figure 56: Error Covariance

4.5.2. Outcomes Covariance

For designs with a Gaussian covariate, the user must specify the covariance of the outcomes, $\boldsymbol{\Sigma}_Y$. For each independent sampling unit, $\boldsymbol{\Sigma}_Y$ is the covariance of the outcomes conditional on the fixed predictors. One can think of $\boldsymbol{\Sigma}_Y$ as the error covariance for each independent sampling unit in a model containing only the fixed predictors and excluding the Gaussian covariate. The *Outcomes Covariance* screen allows the user to define $\boldsymbol{\Sigma}_Y$ by directly entering the covariance matrix values, as shown in Figure 57. To ensure conformance with the $\boldsymbol{B}$ and $\boldsymbol{U}$ matrices, the dimensions of the $\boldsymbol{\Sigma}_Y$ matrix cannot be modifed on this screen.

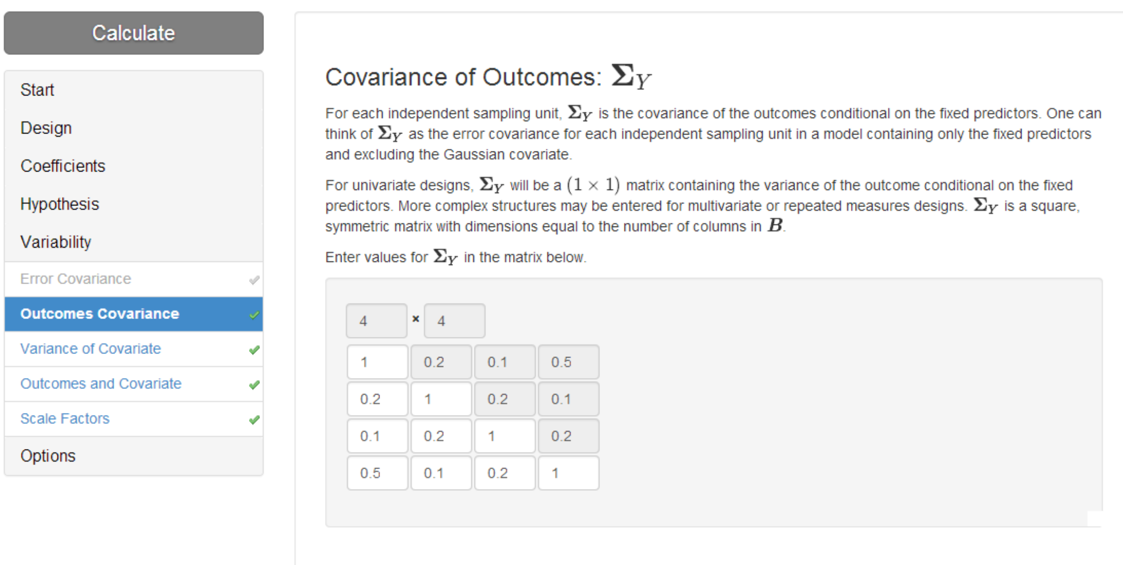


Figure 57: Outcomes Covariance

4.5.3. Variance of Covariate

For designs with a Gaussian covariate, the covariate is assumed to have a Gaussian distribution with mean zero and variance σ_g^2. The *Variance of Covariate* screen allows the user to enter a value for σ_g^2, as shown in Figure 58.

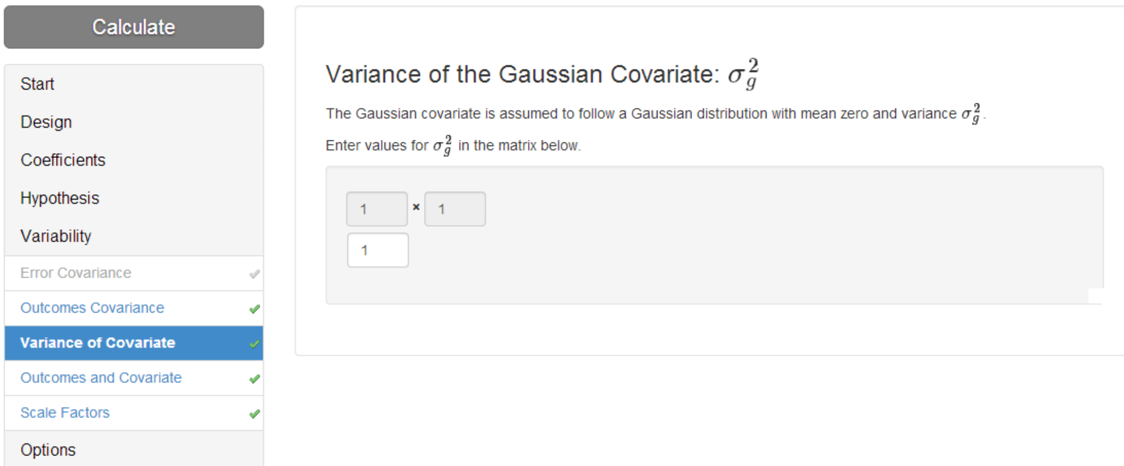


Figure 58: Variance of Covariate

4.5.4. Covariance of Outcomes and Covariate

When controlling for a Gaussian covariate, power is typically improved when the covariate explains some portion of the variance in the outcome. The covariance matrix between the outcomes and the Gaussian covariate, $\mathbf{\Sigma}_{YG}$, describes the association between the outcomes and the Gaussian covariate. The *Covariance of Outcomes and Covariate* screen allows the user to specify values for $\mathbf{\Sigma}_{YG}$, as shown in Figure 59. To ensure conformance with the $\mathbf{\Sigma}_Y$ matrix, the dimensions of the $\mathbf{\Sigma}_{YG}$ matrix cannot be modifed on this screen.

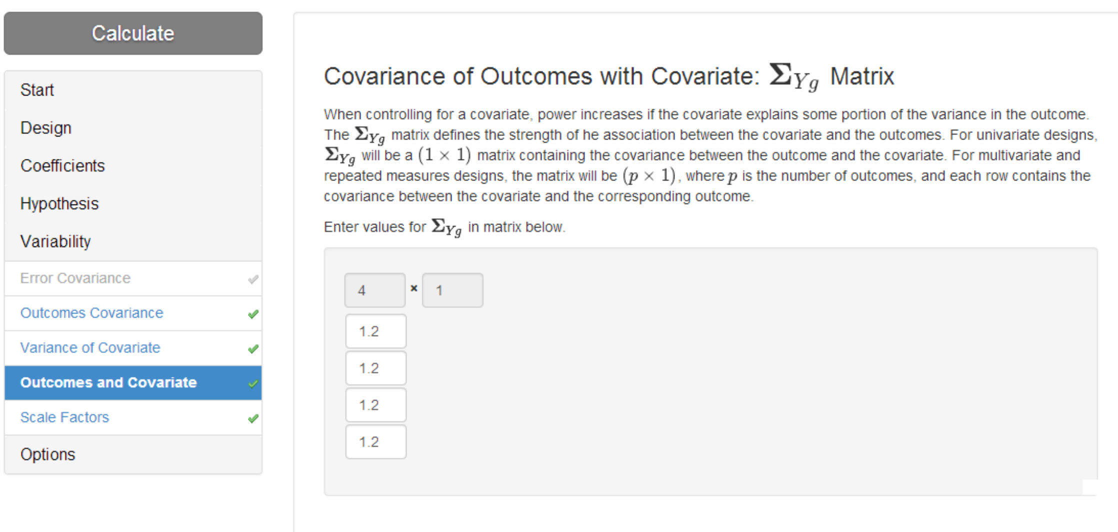


Figure 59: Covariance of Outcomes and Covariate

4.5.5. Sigma Scale Factors

GLIMMPSE allows users to specify scale factors for the covariance matrices. For the general linear multivariate model with fixed predictors, the scale factors are applied to the user-specified $\mathbf{\Sigma}_e$ matrix. For the general linear multivariate model with fixed predictors and a Gaussian covariate, the scale factors are applied to the $\mathbf{\Sigma}_e$ matrix, which is calculated from $\mathbf{\Sigma}_Y$, $\mathbf{\Sigma}_g$, and $\mathbf{\Sigma}_{Yg}$. Since variability can dramatically impact power, it is common to calculate power for the proposed value, as well as alternative values such as half and twice the proposed value.

To specify one or more covariance scale factors, enter the scale factors in the Σ_E *Matrix Scale Factors* box. After each entry,press $\boxed{\text{Enter}}$ on the keyboard. To delete a value, select the unwanted value and click ✖ to remove the value from the list, as shown in Figure 60.

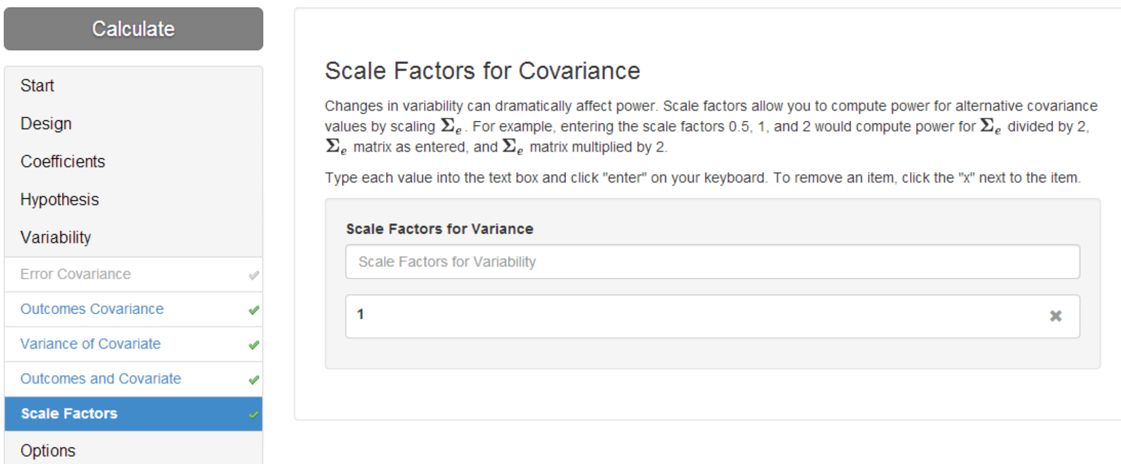


Figure 60: Covariance Scale Factors

4.6. Options

The screen shown in Figure 61 provides an introduction to the Options section.

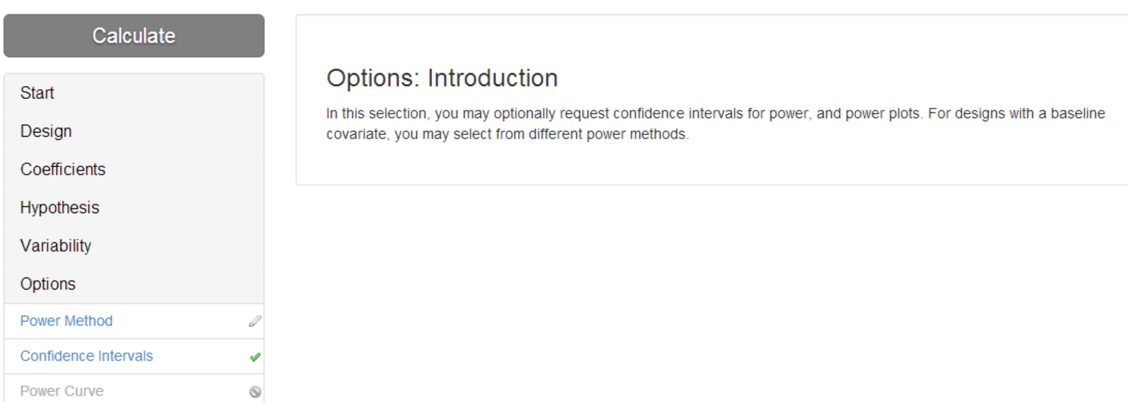


Figure 61: Options

4.6.1. Power Calculation Method

For designs with a baseline covariate, two different methods are available to calculate power: quantile and unconditional power. For theoretical details, please see Glueck and Muller (2003). Select the power methods by clicking the checkboxes shown in Figure 62. If quantile power is selected, the user must also specify one or more quantile values. For example, median power would be obtained by selecting *Quantile* and entering *0.5* in the *Quantiles* list box.

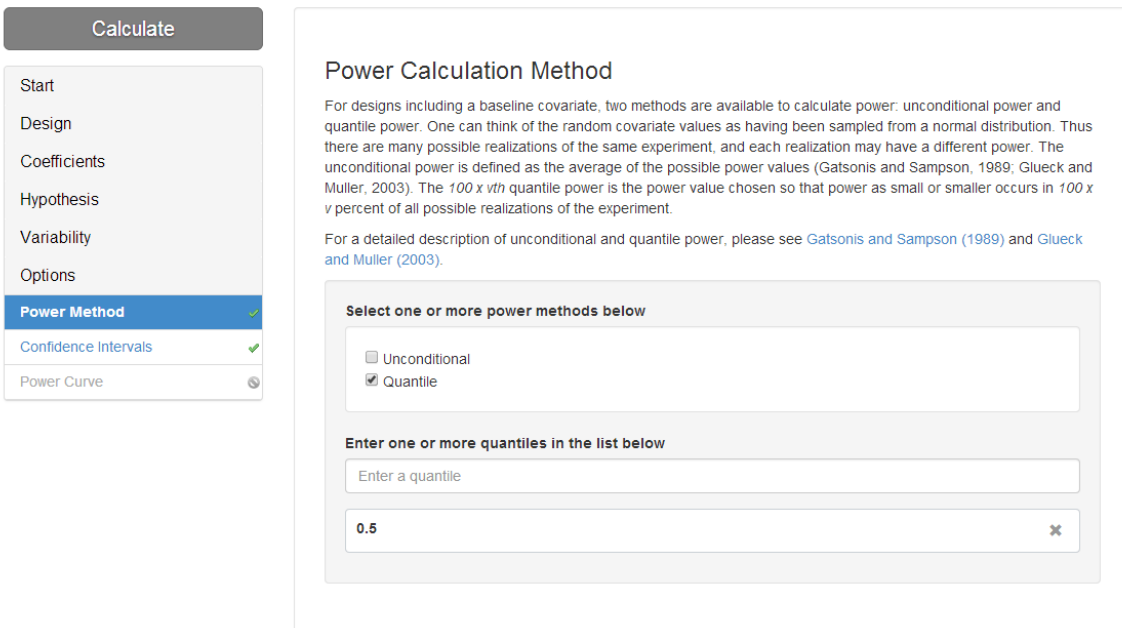


Figure 62: Power Method

4.6.2. Confidence Intervals

Power analysis involves some uncertainty in the choices for means and variability. Therefore, the *Confidence Intervals* screen allows the user to request confidence intervals on the power results. To include confidence intervals, uncheck the checkbox. The information on the confidence interval screen, shown in Figure 63, describes the data set (or publication) from which the choices for means and variances were obtained. For example, if a scientist was calculating power based on the means and variances obtained from pilot data, the scientist would enter information describing the pilot data set. The following information is required:

The *Assumptions* section allows the user to indicate if he or she is uncertain about the variance, but reasonably certain of the mean values, or uncertain of both the means and variance.

The *Upper and lower tail probabilities* define the width of the confidence interval. For example, a centered 95% confidence interval would have both upper and lower tail probabilities of 0.025.

The *Total sample size* value indicates the number of independent sampling units in the pilot data set (or publication).

The *Rank of the design matrix* describes a property of the predictor matrix used in the pilot data set. Please see Muller and Stewart (2006) for details about matrix rank.

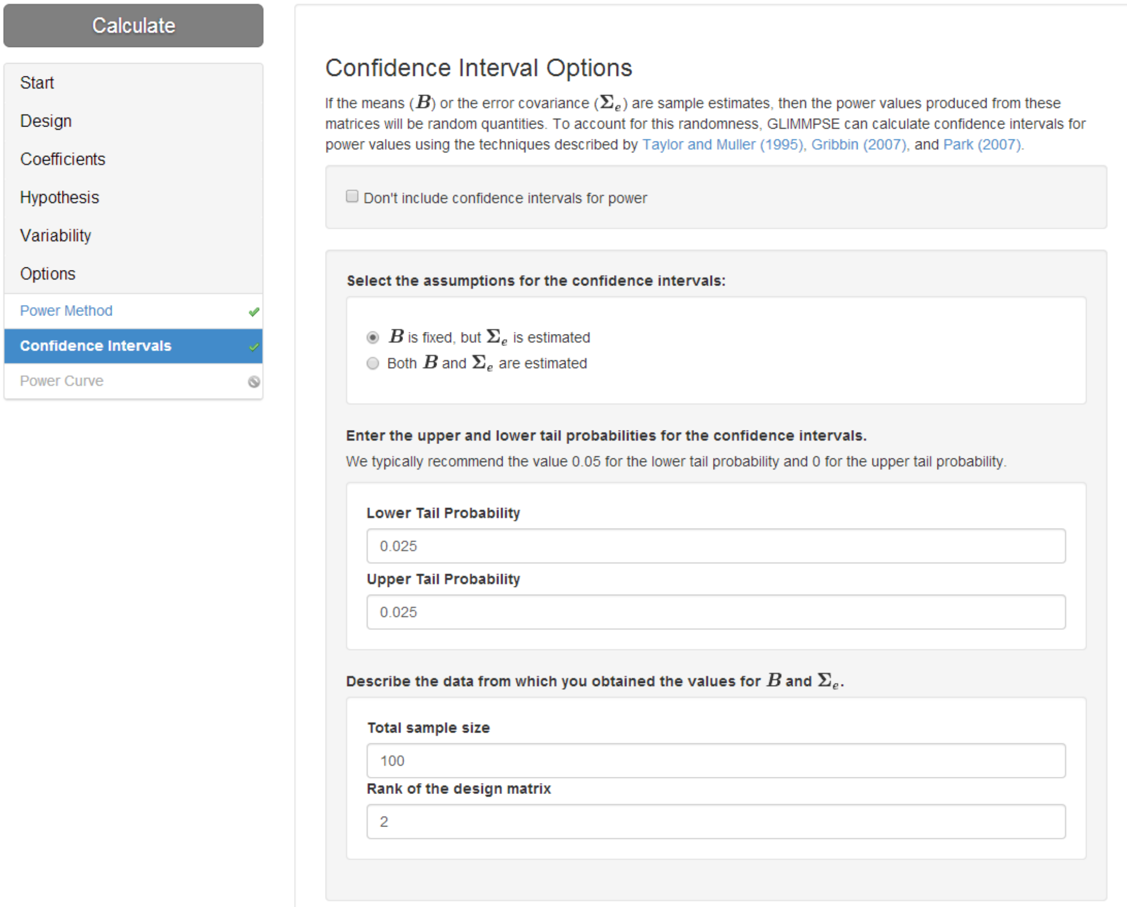


Figure 63: Confidence Intervals

4.6.3. Power Curve Options

The *Power Curve Options* screen allows the user to create a power curve. A power curve describes the change in power (Y axis of the power curve) relative to the total sample size, regression coefficient scale factor, or the variability scale factor (all options for the X axis of the power curve).

To create a power curve, the user must 1) uncheck the check box, 2) select the value to appear on the horizontal axis, and 3) add one or more data series, as shown in Figure 64.

Depending on the study design, the user may request a large number of power or sample size values in a single request. A data series is defined by selecting a subset of the power or sample size values. The user creates a data series by selecting values for several study design variables and clicking the appropriate checkboxes. A data series will be displayed as a single line on the power curve plot.

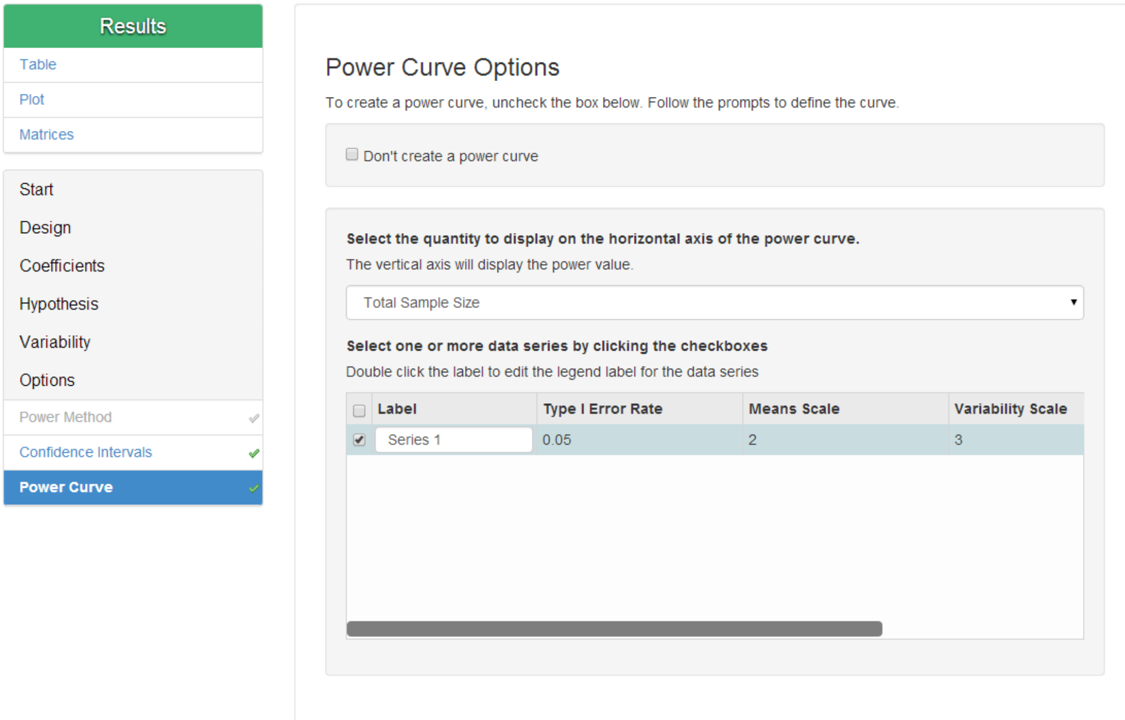
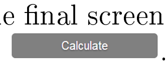


Figure 64: Power Curve

Note that the *Power Curve Options* screen is the final screen in the GLIMMPSE wizard. If the study design is not complete, the Calculate button will be disabled 

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4.7. Calculate

When sufficient information has been entered for your power or sample size calculation, the *Calculate* button will be highlighted green. Click 

to receive the results of your power analysis. Example results are shown in Figure 65. For detailed information regarding the Power Results table, refer to Table 1. The resulting power curve is shown in Figure

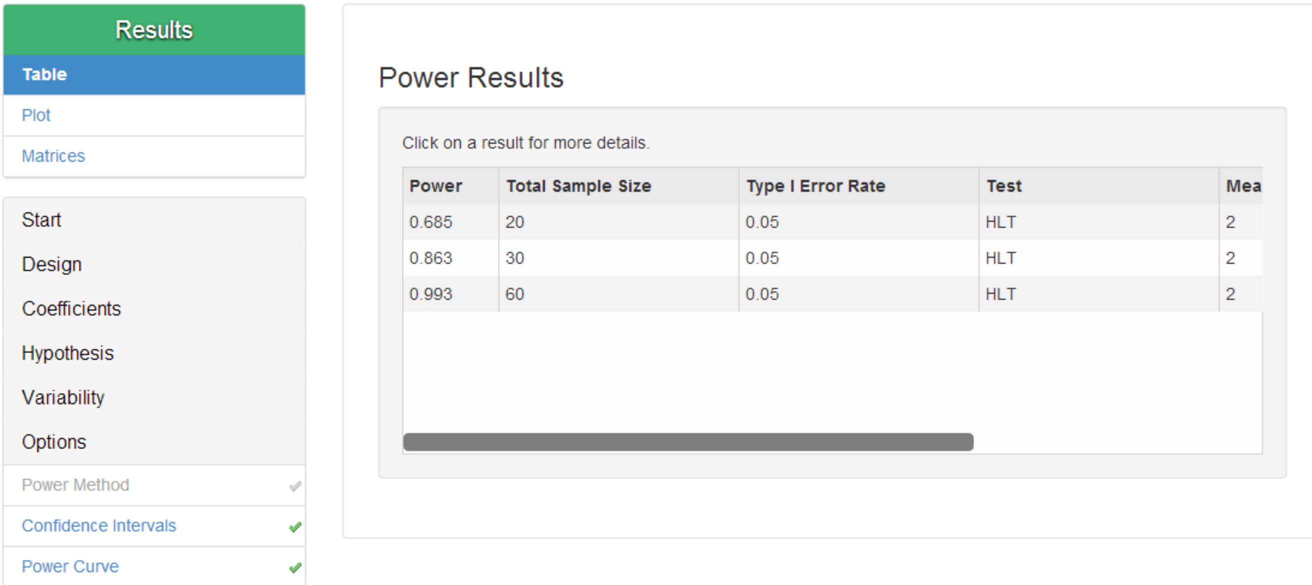

Figure 65: Results Table

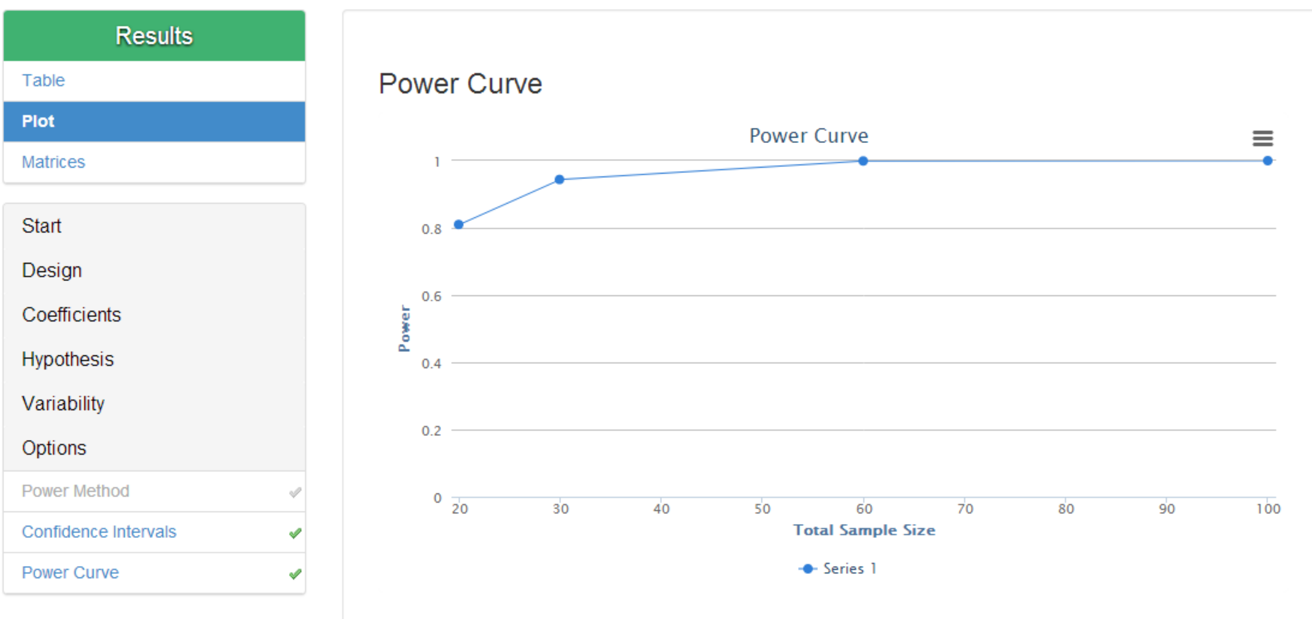

Figure 66: Results Plot

5. Additional GLIMMPSE Resources

Additional resources for GLIMMPSE are available at http://samplesizeshop.org. The Sample Size Shop project is a collaborative effort between the University of Florida and the University of Colorado Denver. The goals of the project are to develop new statistical methods for calculating power and sample size, provide user friendly software to perform the power and sample size calculations, and educate researchers regarding both the methods and the software. The following online resources are available for the GLIMMPSE software.

1. Tutorials demonstrating power and sample size calculations with GLIMMPSE for a variety of study designs are available at http://samplesizeshop.org/education/tutorials
2. Validation reports showing the accuracy of GLIMMPSE calculations are available at http://samplesizeshop.org/documentation/glimmpse/glimmpse-validation-results-2/
3. Technical documentation for the software is available at http://samplesizeshop.org/documentation/glimmpse/
4. GLIMMPSE software modules are available for downloaded from http://samplesizeshop.org/software-downloads/glimmpse-software-downloads/

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