



# **BESA Statistics Manual**





# BESA®

## Statistics 1.0

# Manual

### Copyright and Trademarks

The BESA Statistics product and its documentation are copyrighted © 2014 by BESA GmbH. All rights reserved.

BESA® is a registered trademark of BESA GmbH, Graefelfing, Germany.

All other trademarks, brands and product names used in this guide are trademarks of the respective owners.

Document: BESA Statistics 1.0 Manual

Revision number: 004

Revision date: February, 2014

## Table of Contents

<b>1.</b>	<b>Notes .....</b>	<b>5</b>
<b>2.</b>	<b>Indications for Use .....</b>	<b>5</b>
<b>3.</b>	<b>Product Classification and Certification.....</b>	<b>6</b>
3.1.	Classification .....	6
3.2.	Certification .....	6
<b>4.</b>	<b>System Requirements .....</b>	<b>6</b>
<b>5.</b>	<b>Disposal Information .....</b>	<b>7</b>
<b>6.</b>	<b>Installation and Initial Setup .....</b>	<b>7</b>
6.1.	Before Setup .....	7
6.2.	Installation .....	7
6.3.	Initial setup .....	7
6.3.1.	Connect the BESA Dongle .....	7
6.3.2.	Start the Program.....	9
6.3.3.	Specify the BESA Statistics Data Folder.....	9
<b>7.</b>	<b>Introduction .....</b>	<b>11</b>
7.1.	Features of BESA Statistics .....	11
<b>8.</b>	<b>Statistical Methods .....</b>	<b>12</b>
8.1.	Preliminary t-Test (parametric).....	12
8.2.	Permutation Test (non-parametric) .....	12
<b>10.</b>	<b>The Workflow Concept .....</b>	<b>15</b>
<b>11.</b>	<b>Elements of the BESA Statistics Screen .....</b>	<b>17</b>
11.2.	Workflow Window.....	18
11.3.	Main Window.....	18
11.4.	Interaction Window.....	18
11.4.1.	Notes.....	18
11.5.	Information Window.....	18
<b>12.</b>	<b>Program Bars.....</b>	<b>19</b>
12.1.	Menu Bar.....	19
12.1.1.	File Menu .....	19
12.1.2.	Edit Menu.....	19
12.1.3.	View Menu .....	19
12.1.4.	Export Menu .....	20
12.1.5.	Help Menu.....	20
12.2.	Title Bar .....	20
12.3.	Toolbar .....	20
12.4.	Caption .....	21
<b>13.</b>	<b>How to use BESA Statistics .....</b>	<b>22</b>
13.1.	Starting BESA Statistics .....	22

13.1.1.	Welcome Screen.....	22
13.1.2.	The select Project Page .....	22
<b>14.</b>	<b>The Workflow of BESA Statistics.....</b>	<b>24</b>
14.1.	The Workflow.....	24
14.2.	Set Project Targets.....	24
14.3.	Loading Data .....	25
14.3.1.	Loading Data that were created in BESA Research .....	27
14.3.2.	Loading data that were created in other software .....	28
14.4.	Set Parameters, Preliminary t-test.....	28
14.4.1.	Starttime, Endtime (Start Frequency, End Frequency) .....	29
14.4.2.	Statistical Settings.....	29
14.5.	Perform Statistics.....	31
<b>15.</b>	<b>Analyzing ERP / ERF data.....</b>	<b>33</b>
15.1.	Set Project Targets .....	33
15.2.	Load Data .....	33
15.3.	Set Parameters.....	35
15.4.	Perform Statistics.....	36
<b>16.</b>	<b>Analyzing Source Waveforms .....</b>	<b>39</b>
16.1.	Set Project Targets .....	39
16.2.	Load Data .....	39
16.3.	Set Parameters.....	41
16.4.	Perform Statistics.....	42
<b>17.</b>	<b>Analyzing Time Frequency Data .....</b>	<b>45</b>
17.1.	Set Project Targets .....	45
17.2.	Load Data .....	45
17.3.	Set Parameters.....	47
17.4.	Perform Statistics.....	49
<b>18.</b>	<b>Analyzing Image Data.....</b>	<b>52</b>
18.1.	Set Project Targets .....	52
18.2.	Load Data .....	52
18.3.	Set Parameters .....	54
18.4.	Perform Statistics.....	55
<b>19.</b>	<b>Exporting Images and Results .....</b>	<b>58</b>
19.1.	Exporting Images.....	58
19.3.	Exporting Statistical Results .....	59
<b>20.</b>	<b>Appendix .....</b>	<b>59</b>
20.1.	How to deal with bad channels when analyzing ERP / ERF data .....	59
20.1.1.	Interpolating bad channels in BESA Research .....	60
20.1.2.	Creating a channel montage only containing good channels in BESA Research....	60
20.2.	How to deal with re-montaged or re-referenced data .....	60
<b>21.</b>	<b>File Formats .....</b>	<b>61</b>

---

21.1.	The BESA Statistics Time-Frequency File Format (*.tfc).....	61
21.2.	The BESA Statistics Channel Definition File Format (*.elp).....	63
21.3.	The BESA Statistics Solution File Format (*.bsa).....	64
21.4.	The BESA Statistics Image File Format (*.dat).....	65
21.5.	The BESA Statistics Source Waveforms File Format (*.swf).....	68
21.6.	The BESA Statistics ERP / ERF ASCII Vectorized File Format (*.avr).....	68
<b>22.</b>	<b>References .....</b>	<b>69</b>

## 1. Notes

This user manual is a guide to the research product BESA Statistics – a stand-alone software program.

The manual introduces the features, workflows, and the Main Windows and dialogs of the BESA Statistics software. A help function is provided within the software. Press **F1** on the keyboard or select menu item **Help → BESA Statistics Help** for help.

Before starting to work with BESA Statistics, please read this user manual carefully.

Please report any suggestions and errors found in this manual via email to [feedback@besa.de](mailto:feedback@besa.de).

BESA GmbH provides support to all customers who have purchased BESA Statistics directly from our sales office ([sales@besa.de](mailto:sales@besa.de)) or through our distributors.

BESA GmbH  
Freihamer Str. 18  
82166 Gräfelfing - Germany

**Support:** <http://besa.de/contact/support/form.php>

## 2. Indications for Use

BESA Statistics is a software-only product compatible with personal computers running under a Windows operating system or an emulator thereof. The software is intended to statistically compare results of EEG / MEG data analysis between two groups of subjects or conditions.

BESA Statistics integrates optimally with data that were analyzed in BESA Research, but it can also process data from other software packages as long as they conform to the BESA Statistics file format.

It is possible to compute cross-subject statistics of event-related potentials / fields (ERP / ERF), source waveforms, images, time-frequency data, coherence values and (inter-trial) phase-locking values.

The statistical method is permutation testing on the basis of Student's t-tests. If applicable, permutation tests run on temporal, frequency and / or spatial clusters, thus enabling the best-possible control of multiple comparisons without restricting statistical power unnecessarily.

BESA Statistics software is licensed for research use only.

### 3. Product Classification and Certification

#### 3.1. Classification

According to **MDD 93/42/EEC**, Annex IX, rule 10, BESA Statistics is a **Class Im** software product for the statistical analysis of EEG / MEG data across subjects.

According to safety classifications in **DIN/EN IEC 62304:2006**, BESA Statistics is a **Class A** product (class A: no injury or damage to health is possible).

The product is noninvasive since it is stand-alone software and does not control any equipment physically connected to a patient. It is designed purely for data analysis. No physical devices are controlled or driven by BESA Statistics, nor is any active feedback provided to the patient. Any direct physical damage to the patient, for example, during the recording of data, can therefore be excluded.

According to **DIN EN IEC 60601-1:2005**, BESA Statistics does not affect the possibility of using the computer within a patient environment. BESA Statistics does not interfere with other programs or hardware connected to the computer (third-party equipment)

BESA Statistics is classified with the following codes:

GMDN collective term: CT112 (Software, application program)

#### 3.2. Certification



The CE marking certifies that this product fulfills the basic requirements of the Medical Devices Directive **MDD 93/42/EEC**.

The number represents the identification number of the Notified Body that carried out testing and certification.

### 4. System Requirements

- Operating system: Windows® 8 (Touch not supported)  
Windows® 7  
Windows® Vista  
Windows® XP Service Pack 2
- CPU: Minimum 2 GHz
- RAM: Minimum 2 GB
- Display resolution: Minimum 1280x800 pixels
- Graphics card: OpenGL 1.1 with 16 MB RAM or more



## 5. Disposal Information

The BESA dongle and the BESA Statistics CD must be disposed of according to the national guidelines on environmental protection.

## 6. Installation and Initial Setup

The installation and initial setup of BESA Statistics must be carried out by an administrator or an experienced technician. Chapter 0 illustrates the installation process, and chapter 6.3. introduces the initial setup of BESA Statistics.

### 6.1. Before Setup

**BESA Statistics is available as a 32 bit or a 64 bit program.** The latter version prevents memory problems caused by a 32 bit restriction. Therefore, **we recommend using the 64 bit version** if your Windows system supports it. Please make sure to check this before the installation.



### 6.2. Installation

1. Start Windows and insert the installation disk into the CD-ROM drive.
2. If the PC permits auto start from the CD drive, the installation starts automatically after a short time. If the PC does not permit auto start, please run **Setup.exe** from the CD. The file is located in the **Setup** folder.
3. Please follow the on-screen instructions.
4. Once the installation is complete, proceed with the initial setup as explained in the following chapter.

### 6.3. Initial setup

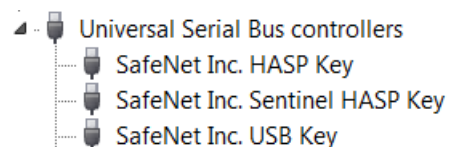
The following section explains the steps for the initial setup of BESA Statistics. These steps have to be performed only once per installation.

#### 6.3.1. Connect the BESA Dongle

BESA Statistics is protected by a licensing scheme developed by SafeNet Inc. During the installation as explained in chapter 0 the device drivers for the BESA dongles will be installed automatically.

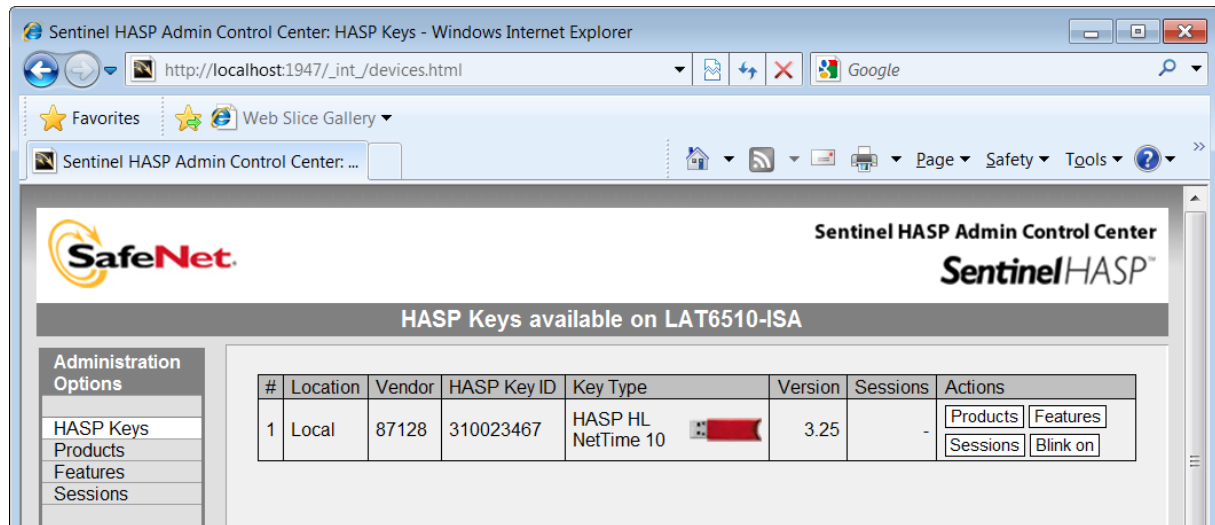
Connect the BESA dongle to your personal computer or a server machine and proceed with the next step. If required, check for correct installation as described below.

If the dongle is installed correctly, the Windows Device Manager reports three items in the "Universal Serial Bus controllers" section: SafeNet Inc. HASP Key, SafeNet Inc. Sentinel HASP Key and SafeNet Inc. USB Key

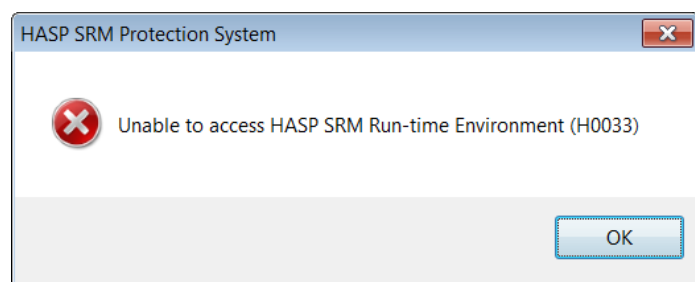
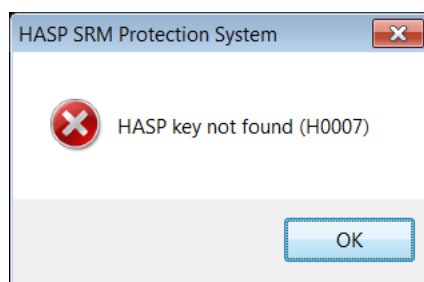


The SafeNet Inc. HASP key installer includes the HASP License Manager application: **C:\Windows\system32\hasplms.exe**

When this application is running, you should be able to load the HASP License Manager Admin Control Center by typing **http://localhost:1947** in your internet browser. The connected dongle should be displayed there. If you do not see the dongle, please wait a few seconds.



If the dongle is not installed correctly, one of the following message boxes is displayed when the program is started.



The message box on the left appears for one of the following reasons:

- The BESA dongle is not connected.

Solution: Ensure that the key is accessible in order to run the program.

- USB port is defective.

Solution: Check if the LED is lit on the HASP Protection Key. If not, remove and re-insert. Wait for the operating system to detect the device. If it still does not light up, try another USB port.

- Faulty dongle.

Solution: On rare occasions, the HASP Protection Keys may be faulty. The dongle does not light up in this case and is not detected in the Device Manager. Request a replacement dongle.

The above right message box comes up for one of the following reasons:

- **C:\Windows\system32\hasplms.exe** is blocked by a firewall or an anti-virus application.

Solution: Add **C:\Windows\system32\hasplms.exe** in the exception list of the anti-virus and firewall applications.

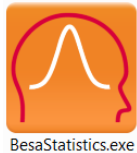
- Port 1947 is blocked by a firewall application.

Solution: Add port 1947 to the exception list of the firewall application.

- HASP License Manager Service is stopped.

Solution: Restart the Sentinel HASP License Manager Service ([Control Panel\System and Security\Administrative Tools → Services](#))

### 6.3.2. Start the Program



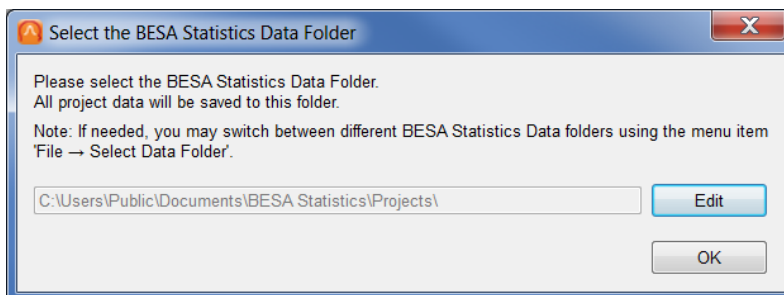
Start BESA Statistics using the shortcut created on the desktop or run **BESA Statistics.exe** from the [All Programs → BESA → Statistics 1.0](#) folder in Startup menu.

First, the Welcome Screen appears (see 13.1.1). Press **Accept** to start BESA Statistics.

### 6.3.3. Specify the BESA Statistics Data Folder

As initial configuration step, the BESA Statistics Data Folder must be specified. This is the folder where BESA Statistics stores all project and result data to and reads from.

When starting the program for the first time, the following dialog box appears:



The BESA Statistics Data Folder is preselected to All Users on the local PC (shown above for Windows 7).

Press the **OK** button if you want to use the preselected local folder in All Users.

Press the **Edit** button to create your BESA Statistics Data Folder elsewhere, e.g. on a server.

When the selection is accepted, the following confirmation dialog appears:



Press the **OK** button.

BESA Statistics is now configured to start projects.

#### **6.3.3.1. Notes**

1. The procedure to define the shared BESA Statistics Data folder on the server needs to be carried out only once at each PC where you install BESA Statistics, i.e. when starting the program for the first time.
2. When switching between BESA Statistics Data folders, it is recommended to leave the tick mark on to update all existing projects in the new BESA Statistics Data folder (see 6.3.3).

## 7. Introduction

### 7.1. Features of BESA Statistics

BESA Statistics provides optimized, user-guided workflows for cross-subject analysis of EEG / MEG data. The statistical method used is parameter-free permutation testing on the basis of Student's t-tests. The program is maximally user-friendly. All analyses are computed automatically with user-interaction minimized to defining time and / or frequency ranges of interest. Statistical values computed in BESA Statistics can be directly used for scientific reports. No further analysis in other programs is needed. All results are visualized and can be directly used for publications.

BESA Statistics integrates optimally with data that were analyzed in BESA Research, but it can also process data from other software packages as long as they conform to the BESA Statistics file format.

BESA Statistics will automatically identify clusters in time, and if applicable frequency and space that show significant and stable differences between two groups or conditions. Results are corrected for multiple comparisons as only those data periods will be marked significant that survive the data re-shuffling of the permutation test. Thus, results obtained by BESA Statistics are objective and robust.

There are three worksteps in BESA Statistics:

1. Loading data and selection of data type (see 14.2 and 14.3)

- ERP /ERF data
- Source waveforms
- Time-frequency data
- Coherence values
- (Inter-trial) phase-locking values

2. Preliminary statistics (see 14.4)

An initial t-test will be computed to retrieve a preliminary statistical comparison between groups / conditions. This can be used to define time-windows and /or frequency-windows of interest that will be passed on to permutation testing. The t-test is described in more detail in chapter 8.1.

3. Permutation testing (14.5)

A permutation test will run on the time and / or frequency period as defined in 2). The generated results will show clusters in time, frequency and / or space that robustly distinguish between the two input conditions or groups. The permutation test is described in more detail in chapter 8.2.

## 8. Statistical Methods

### 8.1. Preliminary t-Test (parametric)

As a first step, BESA Statistics calculates a preliminary Student's t-test (Hays 1988) between groups / conditions per data point. A t-test is computed to determine whether there is a significant difference between the mean of two groups / conditions. A t-test is associated with a t-value and a corresponding p-value which indicates the significance of an effect. P-values smaller than 0.05 are generally considered significant. The p-value becomes smaller if the t-value becomes larger. t-values are influenced by the size of the difference between the group / condition means and the size of the variance in both groups / conditions. Generally speaking, the difference between two group / condition means can be small for the test to become significant if the variance in both groups is also small. On the other hand, a large difference between two group / condition means does not automatically imply a significant effect. It is also required that the variance in both groups / conditions is not too large. Apart from the t-value, the p-value is influenced by the degrees of freedom (DF) for the specific test computed. DF are dependent on the number of subjects. The more subjects constitute the groups / conditions, the larger the DF. Larger DF are more likely to be associated with a significant test result, as variance can be estimated more precisely with a larger number of subjects.

A t-test can be paired or unpaired. A paired t-test is appropriate when there is a dependency between the two conditions that are compared. This is generally the case if two conditions in the same set of subjects are compared (e.g. subjects listening to high intensity vs. low intensity tones) or if the same subject is measured twice for the same task (e.g. listening to 1000 Hz tones before and after a training period). An unpaired t-test is appropriate when there is no dependency between the two groups that are being compared. This is generally the case if two different groups of subjects are compared for the same condition (e.g. motor response in left-handed subjects vs. right-handed subjects). The selection of the correct type of t-test is important: in a paired t-test smaller differences between conditions are necessary for the test to become significant in comparison to an unpaired t-test.

Generally speaking, the likelihood of obtaining significant results is higher if a specific hypothesis about the data is tested. When there is no specific hypothesis as to whether one group / condition has higher or lower values than the other group / condition, a two-tailed t-test should be selected. When there is the hypothesis that the first group / condition has higher values than the second group / condition, a one-tailed-right t-test should be calculated. When there is the hypothesis that the second group / condition has higher values than the first group / condition, a one-tailed-left t-test should be calculated.

### 8.2. Permutation Test (non-parametric)

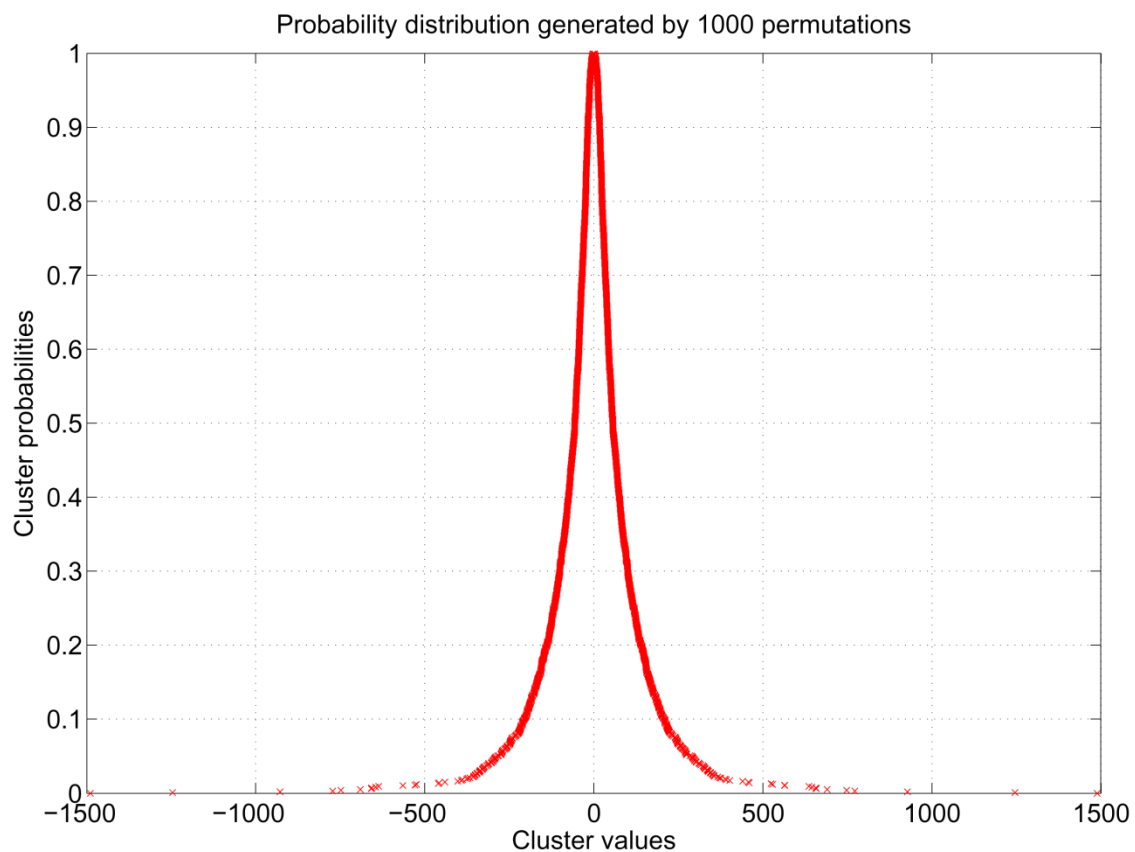
When computing a large number of t-tests, the probability of obtaining a significant result by chance is high. Typically, an  $\alpha$ -error of 5% ( $p$ -value = 0.05) is assumed when calculating statistical tests. Thus, if a significant result is achieved, there is a 5% chance that this result is considered significant although in truth it is not. The more tests are computed, the higher the probability those statistically significant results are obtained by chance.

Statistically analyzing EEG / MEG data usually involves computing a large number of tests, as two conditions are compared for a large number of electrodes over a time interval containing many data samples. Therefore, the multiple comparisons problem is particularly prominent when running statistics on EEG / MEG data.

There are different ways to address the multiple comparisons problem. The easiest is to apply the Bonferroni correction (Abdi 2007), in which the significance level (e.g.  $p = 0.05$ ) is divided by the number of tests computed and only those tests are assumed to be significant with p-values smaller than the corrected value. For example, if 100 tests are computed, the corrected p-value would be  $0.05 / 100 = 0.0005$ . This approach is very conservative and the chance is high that significant results are wrongfully rejected.

BESA Statistics uses an alternative approach to deal with the multiple comparisons problem: Permutation testing in combination with data clustering. The main idea is that if a statistical effect is

found over an extended time period in several neighboring channels, it is unlikely that this effect occurred by chance. Thus, the initial step is to define data clusters that show a significant effect between groups / conditions. For each cluster, a cluster value can be derived consisting of the sum of all t-values of all data points in the cluster. Then it is tested if the initial data clusters survive permutation. Permutation means that the data of subjects (if unpaired t-tests were used) or conditions (if paired t-tests were used) get systematically interchanged. Depending on the number of subjects per group / condition and the type of t-test, a certain number of permutations are possible. For example, if 10 subjects are compared for two conditions using a paired t-test, 1024 ( $2^n$ , where n is the number of subjects) permutations are possible. If 10 subjects are compared with another set of 10 subjects for the same condition using an unpaired t-test, 184756 ( $\binom{n+k}{k}$ , where n is the number of subjects in the larger group, and k is the number of subjects of the smaller group; NB: in this example, the groups are the same size!) permutations are possible. For each of the calculated permutations (default: 1000<sup>1</sup>), a new t-test is computed per data-point. For each permutation, new clusters are determined and the according cluster values are derived for each cluster. Thus, a distribution of cluster-values can be determined across all permutations. Based on this new distribution, the significance of the initial cluster value can be directly assigned. For example, if only 2% of all cluster values are larger than the initial cluster value, the initial cluster can be considered significant with a p-value of 0.02 (one-sided test). Thus, based on the computed cluster-value distribution, the significance of each initial cluster can be directly determined (see Figure 1).



**Figure 1** A realistic distribution of cluster values based on 1000 permutations is displayed. The figure indicates that a cluster value of 300 is associated with a probability value of  $p=0.05$  (one-sided test), meaning that only 5% of all clusters have values larger than 300.

<sup>1</sup> Drawn randomly without repetitions from all possible permutations. If there are not enough subjects to select 1000 permutations, the number is automatically adjusted to the maximum possible number of permutations.

Depending on the direction of a statistical effect (i.e. condition 1 can have larger or smaller values than condition 2), negative and positive clusters can be found. If a negative cluster is tested for significance, it will survive permutation testing if the initial cluster value is more negative than 95% of all cluster values generated by permutation.

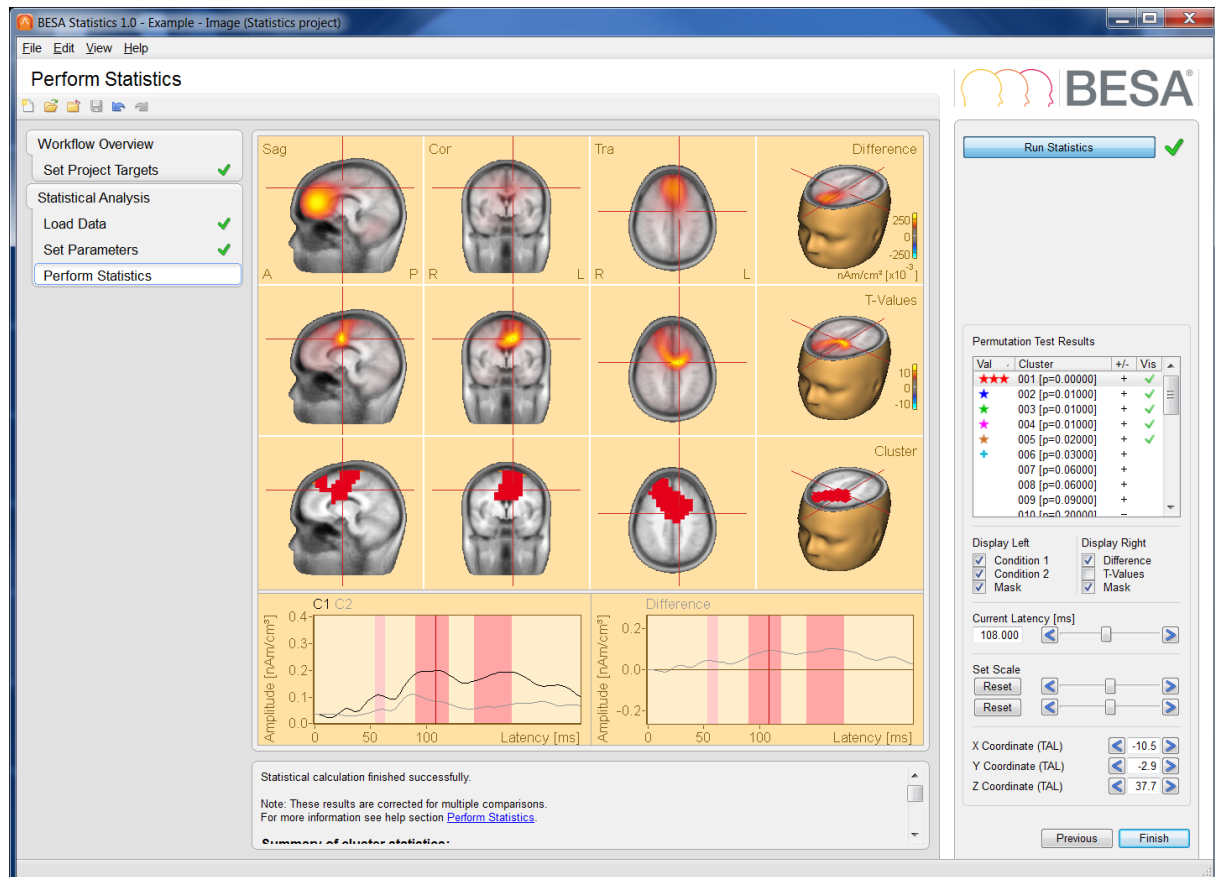
Since in permutation testing the distribution of cluster values is computed from the input data, and p-values are derived directly from the computed distribution, permutation testing is considered non-parametric, or parameter-free. This is a great advantage, since it is not required that data are normally distributed, as would be the case if classic parametric tests were used.

For more details on the implementation of the permutation test as implemented in BESA Statistics please refer to the following publications: (Bullmore, Suckling et al. 1999; Maris and Oostenveld 2007; Ernst 2004)



## 10. The Workflow Concept

BESA Statistics uses a modern workflow concept that guides you through all the worksteps needed to complete a project, suggests and explains necessary inputs and user actions, and performs many worksteps automatically. At any time, you may interrupt and inspect earlier worksteps or redo them with modified input parameters if required.



A workflow consists of a series of worksteps that have to be done to finalize a project. Each workstep realizes a set of user interactions needed to achieve the workstep-specific result. Only few user interactions are needed during the initial worksteps.

When pressing the **Next** button or **Space** a workstep is terminated and the next workstep is loaded. Thus, the workflow of a project sequentially proceeds from workstep to workstep.

The layout of the BESA Statistics screen is optimized for this workflow concept. The workflow menu - as shown on the left in the **Workflow Window** - gives an overview over all the worksteps to be done in the selected project (see 11.1). The workflow menu can be used to switch between the worksteps. For example, you may redo an earlier step with different or advanced parameters and continue with automatic processing of all subsequent steps as defined before.

The current results during a workstep are shown in the **Main Window** in the middle (see 11.3). The **Information Window** below (see 11.5) provides advice and help information for the current workstep.

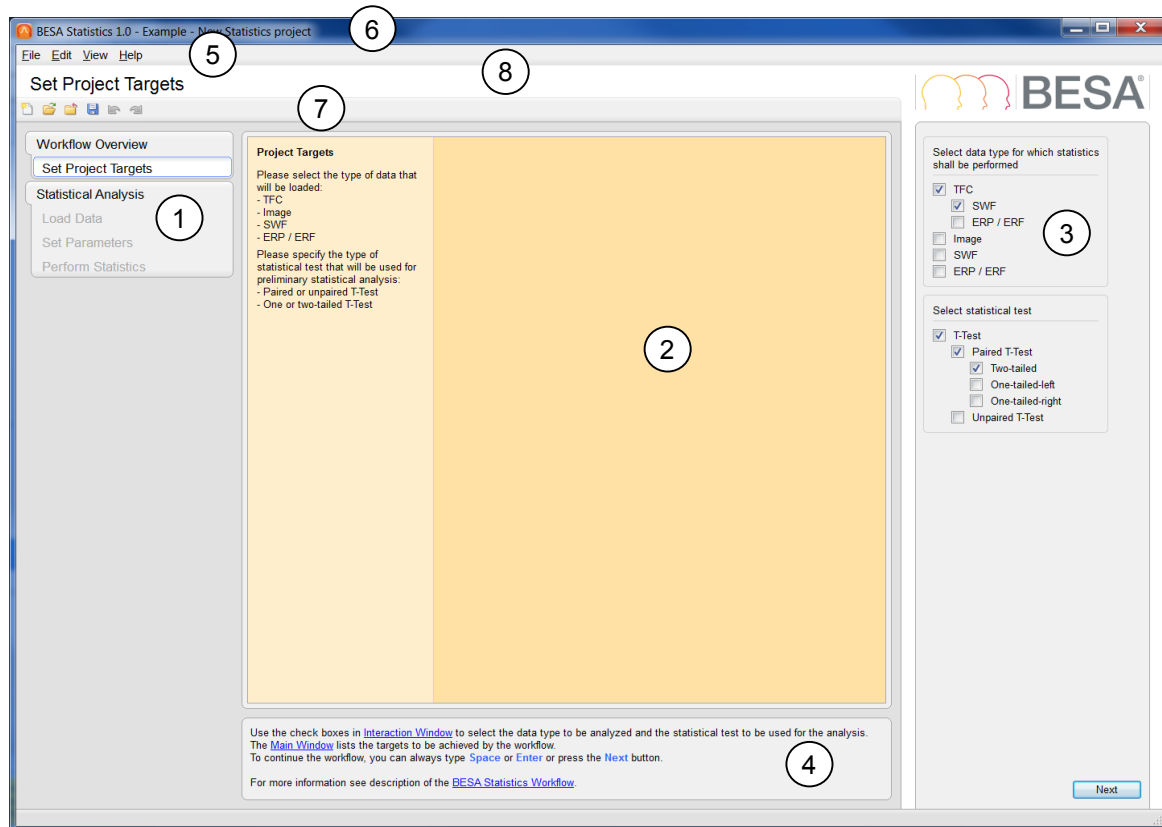
During each workstep a specific dialog is shown in the **Interaction Window** on the right to allow for optimized user interaction relevant for the current workstep (see 11.4). The interactions required during a workstep are grouped starting at the top and ending at the bottom of the Interaction Window. After completing all interactions, press the **Next** button at the bottom or **Space** to proceed to the next workstep. Press the **Previous** button to go back one workstep. After completing the last workstep of the workflow, press the **Finish** button at the bottom of the Interaction Window to save all data created

during the project. This allows reloading the full workflow of a project with all worksteps at any time later.

A project is defined by a specific workflow together with the stored individual input and output data. Stored projects can be viewed by selecting the menu item **File → Open Project**, using the open button in the toolbar, or pressing the **Open Project** buttons on the start screen. After opening a stored completed project, the final workflow result is displayed.

## 11. Elements of the BESA Statistics Screen

The layout of BESA Statistics screen is optimized for the workflow concept as described in chapter 9. The figure below shows the BESA Statistics screen with all its elements:



- 1 Workflow Window (see chapter 11.1)
- 2 Main Window (see chapter 11.3)
- 3 Interaction Window (see chapter 11.4)
- 4 Information Window (see chapter 11.5)
- 5 Menu Bar (see chapter 12.1)
- 6 Title Bar (see chapter 12.1.5)
- 7 Toolbar (see chapter 12.3)
- 8 Caption (see chapter 12.4)

## 11.2. Workflow Window

The Workflow Window on the left displays the workflow menu. The workflow menu gives an overview over the sequential steps needed to finish the current project (for details on the steps see 14). Steps already completed are marked with a green OK sign. ✓

The current workstep is highlighted. This step is also shown in the caption.

The workflow menu can be used like any other menu to jump to another workstep provided that the previous worksteps have already been completed.

## 11.3. Main Window

The Main Window area displays the results of the current workstep. A detailed description how to use the elements shown in this window is given in chapter 14.4.

## 11.4. Interaction Window

The Interaction Window provides the user interaction for the current workstep.

The **upper interaction elements** are used to set parameters needed in the workstep by using standard elements like buttons, edit boxes, and sliders. The effect of changing parameters is seen in the Main Window left of the Interaction Window.

Current parameters are accepted by typing **Space**, or by pressing the **Next** button at the bottom prompting the workflow to proceed to the next workstep.

The **Previous** button is used to jump back to the previous workstep.

### 11.4.1. Notes

1. You can also undo or redo a workstep using the menu items **Edit → Undo** and **Edit → Redo** or by typing **Ctrl-Z** or **Ctrl-Y**.
2. Moving on to the next workstep is fastest by typing **Space** or **Enter**.

## 11.5. Information Window

The information window displays a comprehensive help text related to the current workstep. The help texts provide additional information, e.g. which file has been loaded. They suggest and explain the next user interaction to be done in the current workstep.

Underlined text in blue provides a hyperlink. Click on such a link to open the BESA Statistics help at the indicated topic.

Use the check boxes in [Interaction Window](#) to select the data type to be analyzed and the statistical test to be used for the analysis. The [Main Window](#) lists the targets to be achieved by the workflow. To continue the workflow, you can always type **Space** or **Enter** or press the **Next** button.

For more information see description of the [BESA Statistics Workflow](#).

## 12. Program Bars

### 12.1. Menu Bar

The Menu Bar provides the menus listed below. Click on a menu to be selected and choose from the menu items that pop up.

#### 12.1.1. File Menu

The **File** menu contains the following items:

File menu item	Description
<b>Create New Project</b>	Start a new project.
<b>Open Project</b>	Load an existing project (see 13.1.2).
<b>Close Project</b>	Close currently active project. Show the Select Project Page (see 13.1.2).
<b>Save</b>	Save the currently active project.
<b>Save As...</b>	Specify a filename for currently active project and save it (see 13.1.2).
<b>Delete Projects...</b>	Select one or multiple projects that shall be deleted (see 13.1.2).
<b>Select Data Folder</b>	Select the folder to be used as BESA Statistics Data Folder (see 6.3.3).
<b>Update Data Folder Info</b>	Update the information file in the BESA Statistics Data Folder (see 6.3.3).
<b>Exit</b>	Terminate the BESA Statistics program.

#### 12.1.2. Edit Menu

The **Edit** menu contains the following items:

Edit menu item	Description
<b>Undo</b>	Undo the last step completed in the current workstep.
<b>Redo</b>	Redo the last step that was undone in the current workstep.

#### 12.1.3. View Menu

The **View** menu can be used to change display settings for BESA Statistics. It contains the following entries:

View menu item	Description
<b>Show Workflow Window</b>	By selecting or deselecting this menu item the Workflow Menu is displayed or hidden (see 11.1).

**Show Information Window**

By selecting or deselecting this menu item the Information Window is displayed or hidden (see 11.5).

**Standard Font Size,****Large Font Size,****Extra Large Font Size**

Select one of these menu items to specify the size of the font to be used in BESA Statistics.

### 12.1.4. Export Menu

The **Export** menu can be used for exporting vector graphics (\*.eps) or bitmap images (\*.png) of the main window, the detail windows or a combination of all windows. It also allows exporting the statistical results of the permutation test either as a summary (Cluster and p-values, cluster boundaries) or as detailed means per person / cluster. For a more detailed description of the exporting options please see chapter 19.

Export menu item	Description
<b>Image</b>	Allows exporting images of the main window, the left detail window, the right details window or all windows. In the saving dialogue, the format (*.eps or *.png) can be specified. Images can also be exported by right-clicking in the according window.
<b>Statistical Results</b>	Allows exporting the summary of cluster statistics and detailed results per cluster. Results are saved as comma-separated values.

### 12.1.5. Help Menu

Use the **Help** menu to open the program help or to get information about BESA Statistics.

Help menu item	Description
<b>BESA Statistics Help</b>	Open the program help.
<b>About...</b>	Get information about the current program version.

## 12.2. Title Bar

The title bar of BESA Statistics displays the program name and version number. In addition, it shows information on the current project:

- Group name
- Project name

## 12.3. Toolbar

The Toolbar provides direct access to the most important menu items:

 **File → Create New Project** **File → Open Project** **File → Close Project** **File → Save Project** **Edit → Undo****Edit → Redo**

## 12.4. Caption

The caption is located between the Menu Bar and the Toolbar and specifies the current workstep.

## 13. How to use BESA Statistics

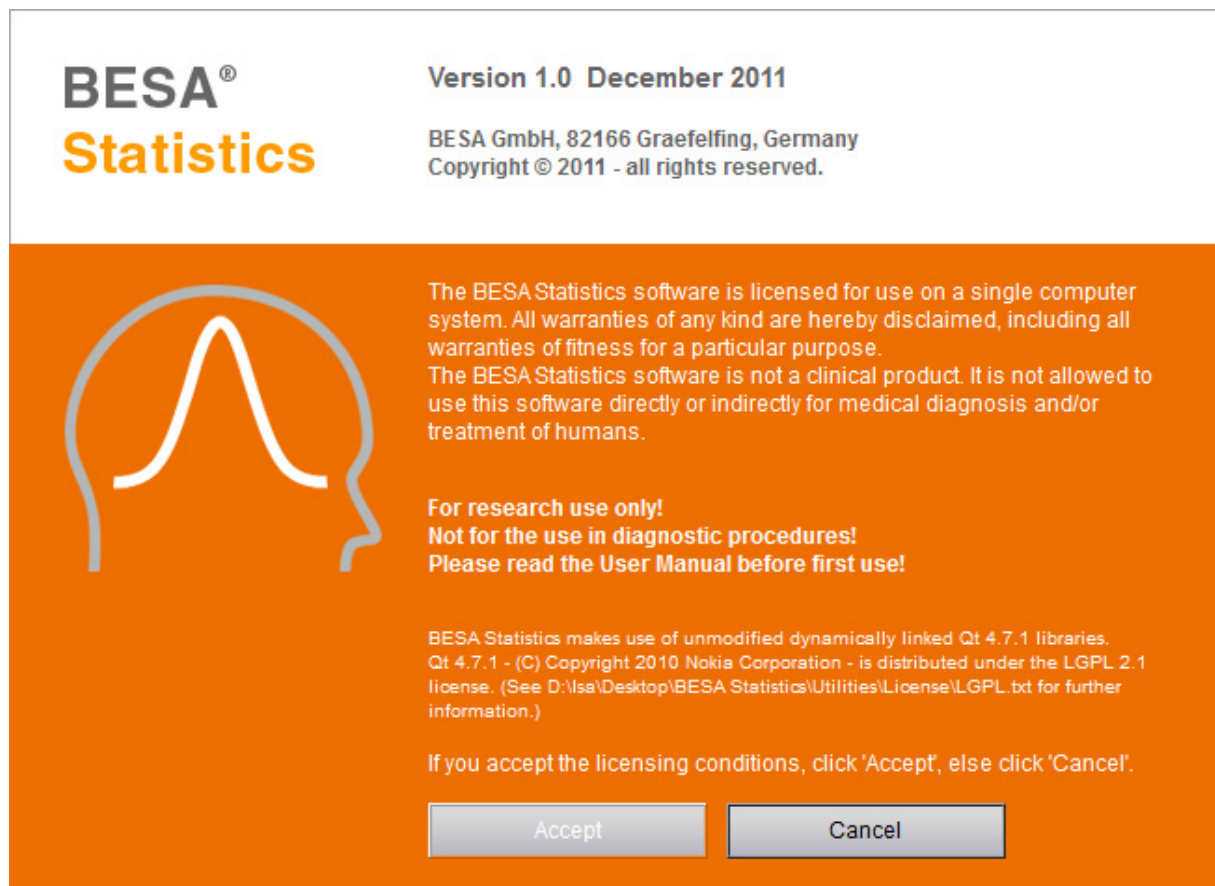
Before working with BESA Statistics, please read chapter 9 on the workflow concept. Consult chapter 11 on the elements of the BESA Statistics screen while starting to use the program.

### 13.1. Starting BESA Statistics

#### 13.1.1. Welcome Screen

Start BESA Statistics from its icon on the desktop.

When starting BESA Statistics, a welcome screen appears. It provides some information on the BESA Statistics program including the current version number and date:



Press **Accept** to start BESA Statistics.

#### 13.1.2. The select Project Page

After starting BESA Statistics, the page Select Project shows.

Press **Start New Project** to create a new statistics project. The Workflow opens (see 11.1).

Press **Open Project** to load an existing project

##### 13.1.2.1. Notes



1. Projects can also be started or opened at any time by selecting the menu items **File → Create New Project** or **File → Open Project**.

## 14. The Workflow of BESA Statistics

### 14.1. The Workflow

The Workflow realizes the selection of the statistical test and type of data, the loading of EEG / MEG data for two groups / conditions, the calculation of a preliminary t-test for further specification of data regions of interest and the calculation of a Cluster Permutation Test. The Workflow consists of the following worksteps:

### 14.2. Set Project Targets

In the first workstep the type of data, which will be subjected to statistical analysis needs to be selected. Permutation testing can run on

- **TFC (Time-Frequency and Coherence):** time-frequency analysis and coherence results in source space (TFC SWF) or sensor space (TFC ERP / ERF)
- **Image:** data derived from distributed source analysis(e.g. LORETA) in a volume<sup>2</sup>
- **SWF (Source waveforms):** data derived from discrete source analysis using single dipoles or regional sources
- **ERP / ERF:** event-related potential /field data (sensor-level) obtained by averaging across trials

The required file format of the different data types is described in chapter File Formats.

After selecting the data type, the statistical method that is used as the base for permutation testing needs to be set. Different types of t-tests (see 8.1) can be selected depending on the type of comparison that is to be computed:

- **Paired t-test:** In case two conditions are compared within the same subjects, a paired t-test should be selected. E.g. The EEG of 10 subjects was measured while they were listening to tones of high and low frequency. The brain response to tones of high frequency is meant to be compared to the brain response to tones of low frequency within the same 10 subjects.
- **Unpaired t-test:** In case two groups of subjects are compared for the same condition, an unpaired-t-test should be selected. E.g. the EEG of a control group and a patient group is measured while subjects are viewing pleasant pictures. The brain response to pleasant pictures is meant to be compared between control subjects and patients.
- **Two-tailed, one-tailed left, one-tailed right:** Generally speaking, the likelihood to obtain significant results is higher if a specific hypothesis about the data is tested. In case there is no specific hypothesis as to whether one group/condition has higher / lower values than the other group/condition, a two-tailed t-test should be selected. In case there is the hypothesis that the first group / condition has higher values than the second group / condition, a one-tailed-right t-test should be selected. In case there is the hypothesis that the second group / condition has higher values than the first group / condition, a one-tailed-left t-test should be selected.

Type **Space** or press **Next** to continue the workflow.

<sup>2</sup> Please note that Minimum Norm solutions are calculated on a standard cortex in BESA Research. Statistical analysis of cortex-based solutions is currently not yet supported.

### 14.3. Loading Data

It is recommended that the data that are to be analyzed by BESA Statistics are organized **into two separate folders**, one folder per condition / group containing as many files as there are subjects. **One of the data folders needs to contain 1 copy of the additional file required for ERP / ERF, TFC and SWF data.** (see 14.3.1).



#### Box 1 Recommended file organization

In this workstep, the data of the previously selected type are loaded (see 14.2). Two sets of data need to be loaded in two different steps:

- In case a **paired t-test** was selected in the previous step, data files for condition 1 will be loaded in the first step and data files for condition 2 will be loaded in the second step. There needs to be one data file per person per condition. The number and order of files in both conditions needs to be the same (see
- Box 2).
- In case an **unpaired t-test** was selected in the previous step, data files for group 1 will be loaded in the first step and data files for group 2 will be loaded in the second step. There needs to be one data file per person per group. The order and the number of files do not have to be the same for both groups of data.

It is crucial for **paired T-Tests** that the **same number of files** is loaded for both conditions and that the **order of the files** is the same for both conditions!

**Correct:**

Data Cond. 1	Data Cond. 2
Subject 1	Subject 1
Subject 2	Subject 2
Subject 3	Subject 3
Subject 4	Subject 4
Subject n	Subject n

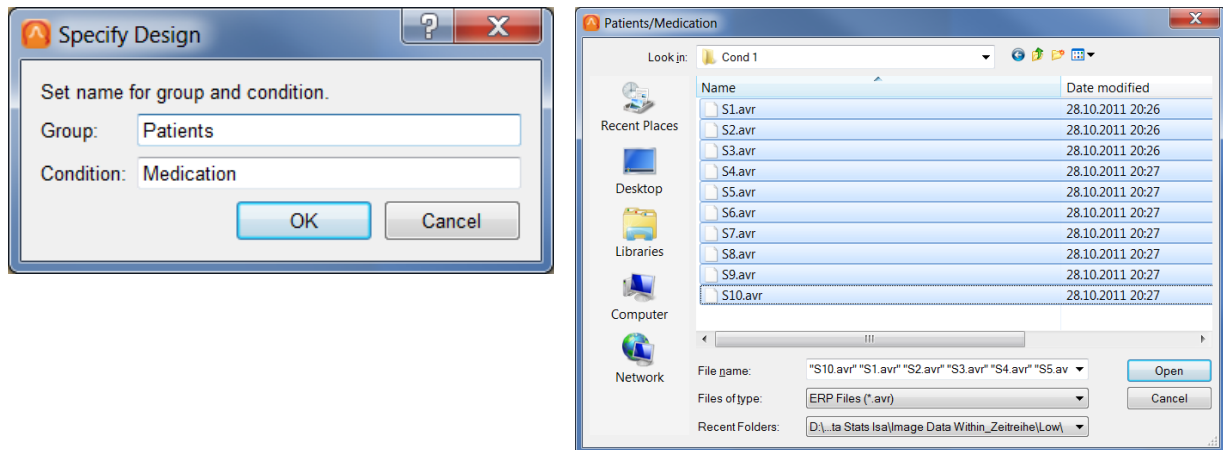
**Incorrect**

Data Cond. 1	Data Cond. 2
Subject 1	Subject 3
Subject 2	Subject 1
Subject 3	Subject 2
Subject 4	Subject 4
Subject n	

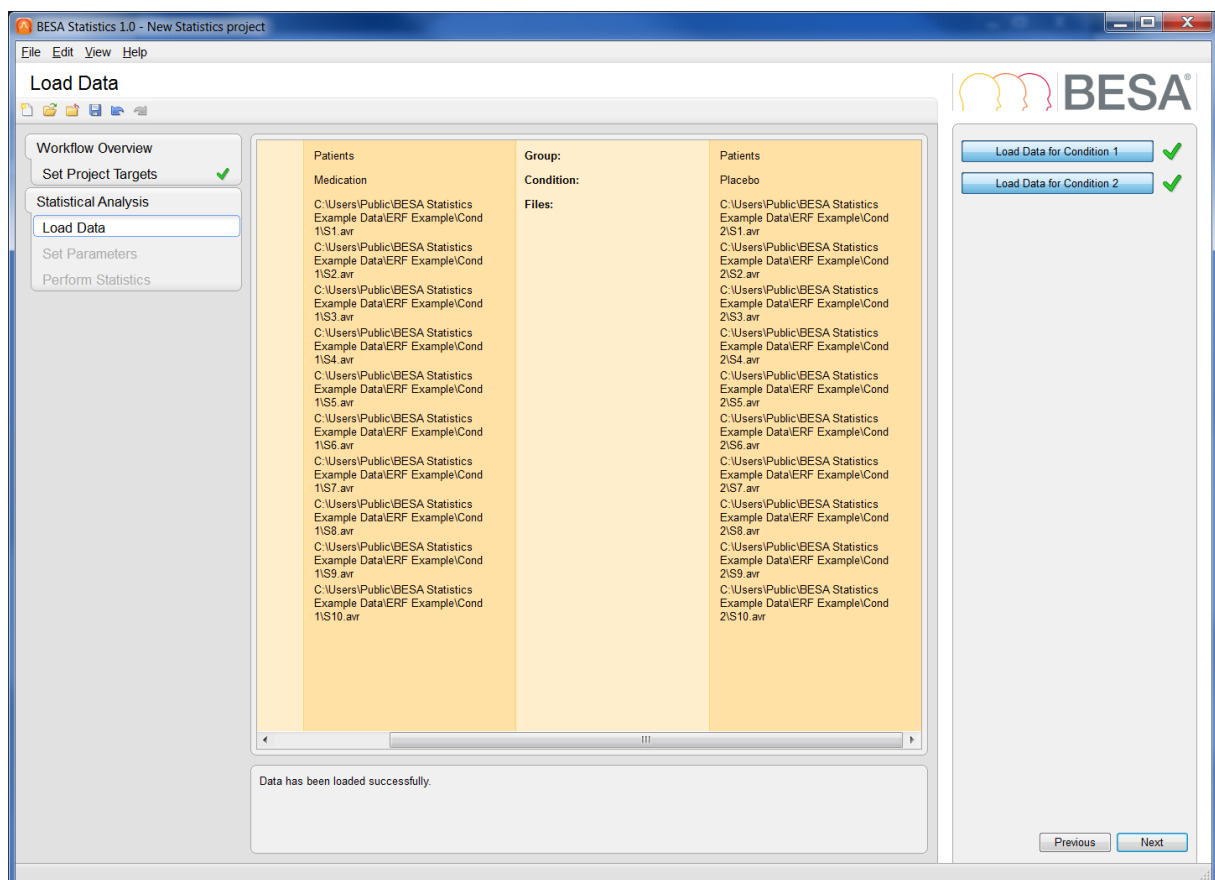


#### Box 2 Data Organization for paired t-tests

Pressing the button **Load Data for Group / Cond. 1** will bring up a dialogue window prompting the specification of the statistical design. A group and a condition name need to be specified. Pressing **OK** will open the file selector box. Please select the first set of files corresponding the first condition / group and press **Open**.



The file names will be listed in the Main Window along with the specified group and condition name. A green tick-mark will be displayed next to the first load button. Type **Space** or press **Next**, or **Load Data for Group 2** to continue the workflow. The dialogue window prompting the specification of the statistical design opens again. This time, only the label for group or condition can be specified, depending on whether a paired or unpaired t-test was selected earlier. If a paired t-test was selected previously only the second condition name can be entered in the dialogue, if an unpaired t-test was selected previously only the second group name can be entered. Pressing **OK** will open the file selector box. Please select the second set of files corresponding the first condition / group and press **Open**. The file names of the second group / condition will also be listed in the Main Window and a green tick-mark will be displayed next to the second load button. The Loading Data workstep is now complete.



Type **Space** or press **Next** to proceed to the next workstep.

### 14.3.1. Loading Data that were created in BESA Research

BESA Statistics expects the loaded data to conform to a certain format. Data that were created in BESA Research automatically follow the format requirements if they are exported the following way:

Data Type	Extension	Description	Data export from BESA Research
<b>TFC ERP / ERF</b>	*.tfc	File containing results from TFC analysis <b>on sensor level</b>	TFC Window: File / Export to ASCII File → Time Frequency Data Files
<b>Additional File</b>	*.elp	Electrode positions	Main Window: File / Head Surface Points and Sensors / Save all Files in Head Coordinates <sup>3</sup>
<b>TFC SWF</b>	*.tfc	File containing results from TFC analysis <b>on source level</b>	TFC Window: File / Export to ASCII File → Time Frequency Data Files
<b>Additional File</b>	*.bsa	Source positions	SA Window: File / Save Solution As → BESA Solution – Unit Sphere <sup>3</sup>
<b>Image</b>	*.dat	File containing solution from distributed source analysis	SA Window: Image / Export Image As → Image ASCII Files (optional: - all latencies)
<b>SWF</b>	*.swf	File containing solution from discrete source analysis	SA Window: File / Save Source Waveforms As → BESA Source Waveforms Files
<b>Additional File</b>	*.bsa	Source positions	SA Window: File / Save Solution As → BESA Solution – Unit Sphere <sup>4</sup>
<b>ERP / ERF</b>	*.avr	File containing event-related potential / field data	Main Window, marked segment: File / Export → Marked segment, ASCII Vectorized <sup>5</sup>
<b>Additional File</b>	*.elp	Electrode positions	Automatically exported with ASCII Vectorized data <sup>6</sup>

<sup>3</sup> The sensor / source positions only need to be saved once per experiment, assuming that the same positions are used for all participants. Source orientations may differ across subjects as BESA Statistics does not display source orientations. BESA Statistics will use the first elp / bsa-file detected in the specified data folders.

<sup>4</sup> Coordinates must be in unit sphere. Talairach coordinates are not yet supported.

<sup>5</sup> Only segmented data are supported, continuous data cannot be analyzed in BESA Statistics.

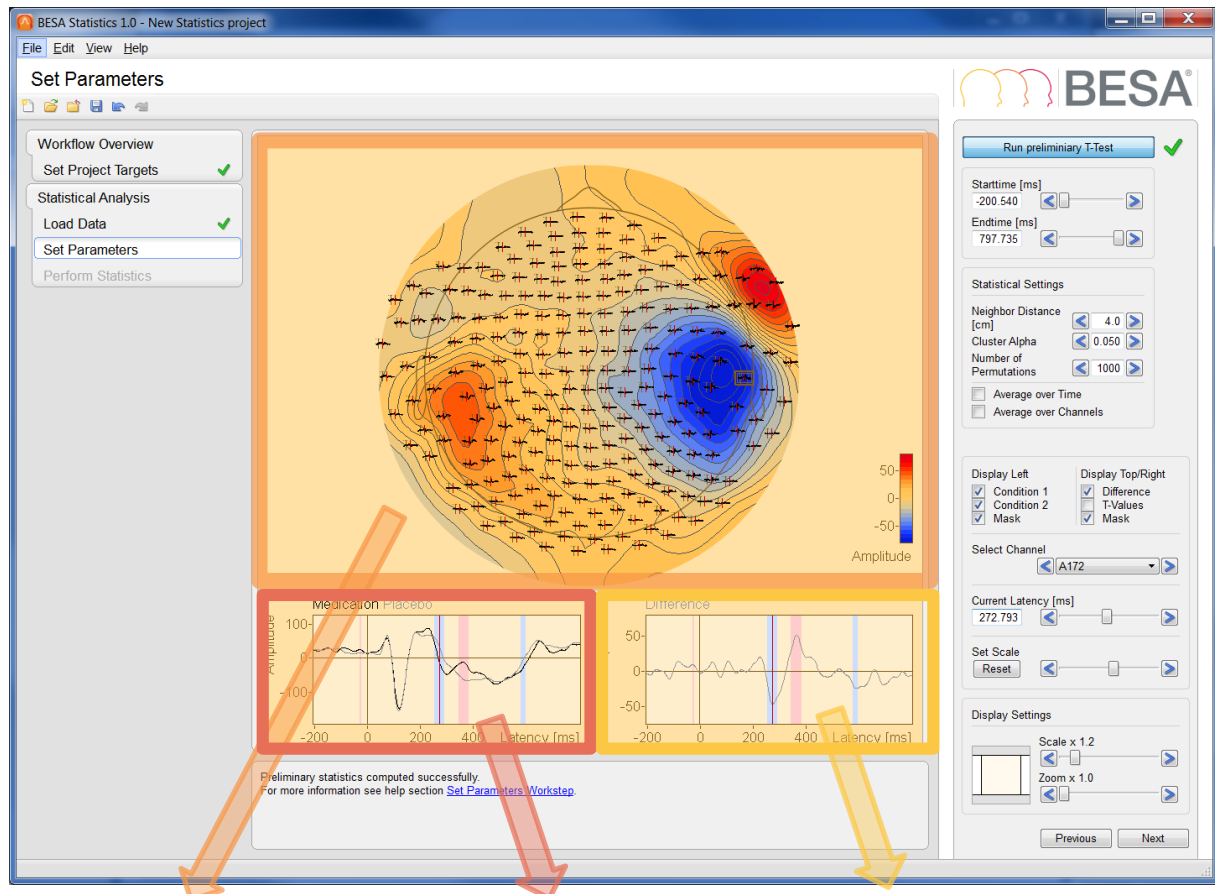
<sup>6</sup> In case bad channels were defined, data were re-referenced or in case a montage was used that only contained a subset of channels, please refer to chapter 19

### 14.3.2. Loading data that were created in other software

In case BESA Statistics is used for data created in other software, files need to be prepared to meet file format expectations. Please see chapter 21 for a detailed file format description.

## 14.4. Set Parameters, Preliminary t-test

After running the preliminary t-test, the test results can be reviewed in order to define a region of interest, set statistical parameters for permutation testing and average over time and / or frequency and channels. The elements of the Interaction Window will be described in the following.



The Main Window shows the difference between groups / conditions or the corresponding t-values per time-point and channel (ERP / ERF), time-point and voxel (image), time-frequency point and channel / source (TFC ERP /ERF or SWF) or the source positions if source waveforms are analyzed.

The left Detail Window displays an overlay of groups / condition of the selected channel (ERP / ERF), voxel (image), source (SWF). For TFC data, only one condition can be displayed at a time. If selected, masks indicating significant clusters determined from the preliminary t-test will be overlaid additionally.

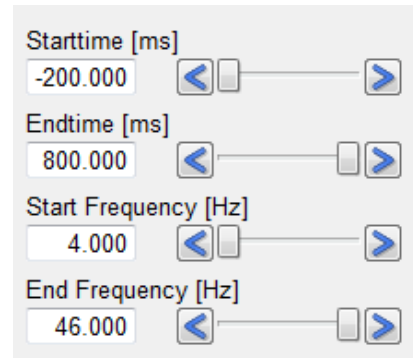
The right Detail Window displays the difference between groups / conditions or the corresponding t-values per time-point and **selected** channel (ERP / ERF), time-point and voxel (image), time-frequency point and **selected** channel / source (TFC ERP /ERF or SWF) or time-point of the **selected** source (SWF). Selections are made in the Main Window or via the channel selection box (see 14.4.2). If desired, masks indicating significant clusters determined from the preliminary t-test will be overlaid additionally.

### 14.4.1. Starttime, Endtime (Start Frequency, End Frequency)

Editing the **Starttime** and **Endtime** and if applicable **Start Frequency** and **End Frequency**, the original data epoch will be adjusted accordingly.

Defining a region of interest can increase the chance that a cluster will be significant after permutation. It will not alter the significance of the target cluster per se unless the selected starttime (frequency) / endtime (frequency) cut the cluster boundaries. Instead, the cluster value of the target cluster will have a different relative position in the cluster value distribution as derived by permutation (see 8.2) when a smaller region of interest is used.

If averages over time are computed, the starttime and endtime selection will impact on the permutation test result.



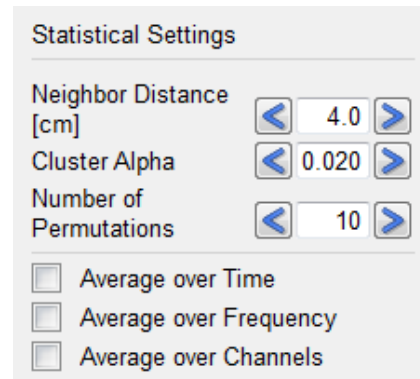
### 14.4.2. Statistical Settings

The **Neighbor Distance** (circle arc length between two points) should be set to reflect the spacing between electrodes / MEG sensors. If the value is set correctly, BESA Statistics will only treat those electrodes / sensors as neighbors that are directly neighboring. If the value is set too low, no spatial clustering will be possible. If the value is set too high, clusters might become larger as also more distant electrodes / sensors are treated as neighbors.

**Cluster Alpha** determines the significance level for building clusters in time and / or space / frequency (see below). After the preliminary t-test is run to compare groups / conditions point-wise, every data point will be associated with a T- and a p-value. When BESA Statistics looks for data clusters showing significant differences between groups / conditions, only those data points are eligible to be part of a cluster, which fall below the Cluster Alpha value. The larger the Cluster Alpha value, the larger the remaining clusters.

**Number of Permutations** determines, how many of all possible permutations (see 8.2) will be computed. If the number is smaller than the number of possible permutations, permutations are determined randomly, no repetitions allowed. If the number is larger than the number of possible permutations, BESA Statistics automatically corrects the value to the amount of possible permutations.

It is possible to **Average over Time** and / or **Frequency** / **Channels** if desired. If selected, BESA Statistics will average across all available data-points of the selected dimension.



**Display Left** defines what will be displayed in the left Detail Window (see 14.4). **Display Top/Right** defines what will be displayed in the Main Window and the right Detail Window (14.4).

**Select Channel** allows the selection of a desired channel (TFC (ERP / ERF)) / source ((TFC) SWF) or Extremum (Image) to be displayed in the Detail Windows via a drop-down menu. Alternatively, the channel / source / maximum of choice can be selected in the Main Window by a left-click. The arrow buttons left and right of the channel selector box can be used to quickly browse through all channels / sources / maxima.

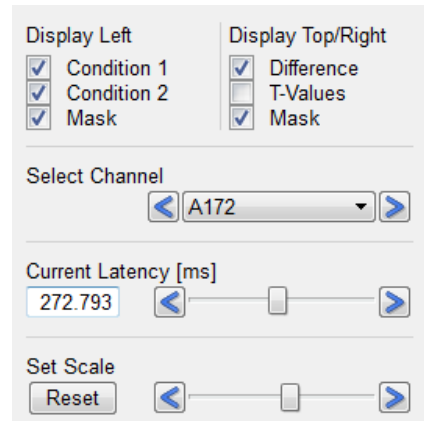
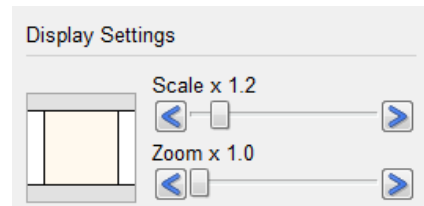
**Current Latency** allows setting a cursor at a particular latency (if TFC data are available, a **Current Frequency** can be selected additionally). The slider can be dragged to the point of interest or the arrow buttons at the left and right of the slider bar can be used to adjust the position.

**Set Scale** (only ERP /ERF) allows adjusting the scaling of the topographic map in the Main Window. The map corresponds to either the difference between conditions or the corresponding t-values, depending on the selection under Display Top/Right. A **Reset** button is available to return to default settings.

**Scale** allows altering the scaling of the data. The arrow buttons at the left and right of the slider bar can be used to scale the data up or down.

**Zoom** allows viewing the Main Window contents in greater detail. The arrow buttons at the left and right of the slider bar can be used to adjust the zoom factor. The black frame at the left of the Zoom slider displays the position of the currently displayed window fraction relative to the complete window. The frame can be left-dragged to another relative position. Alternatively, it is possible to left-drag the Main Window while holding down the control key.

Type **Space** or press **Next** to proceed to the next workstep.

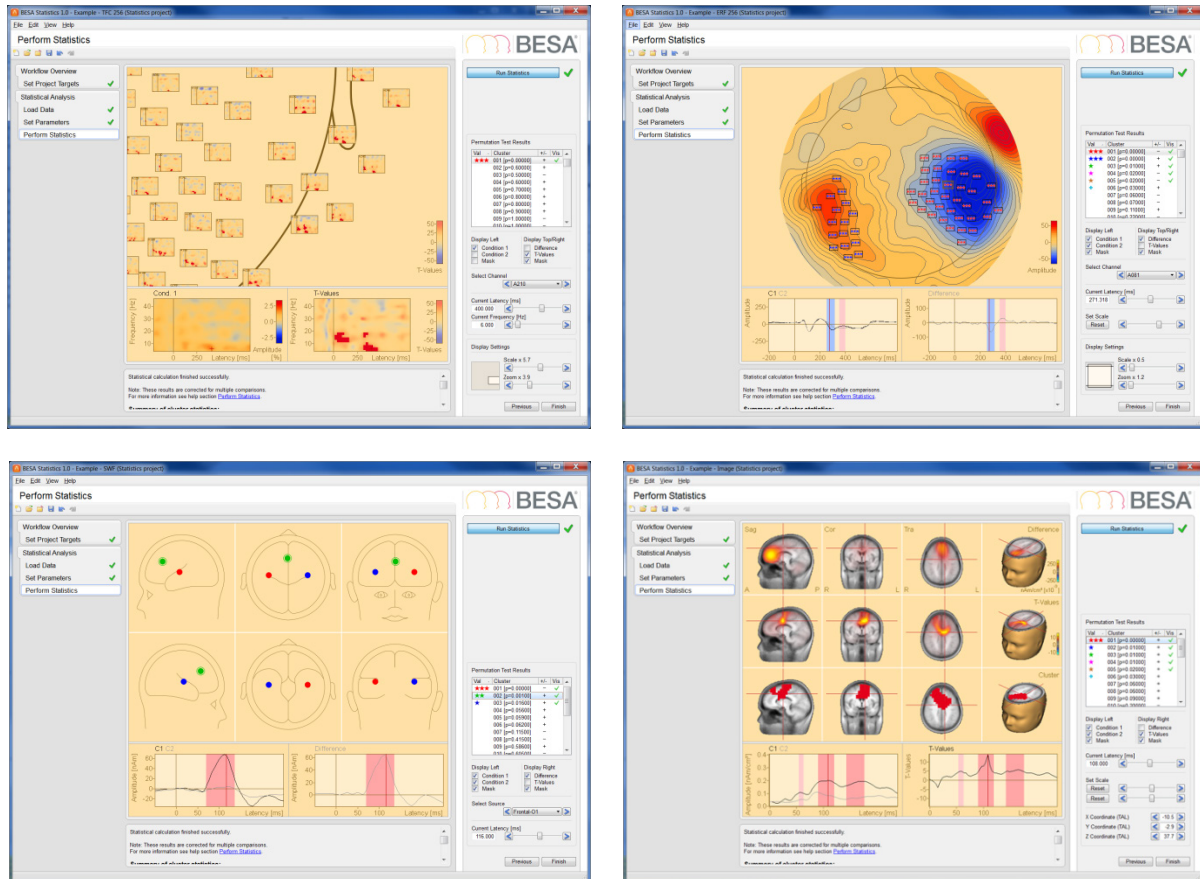





## 14.5. Perform Statistics

Press **Run Statistics** to start the permutation test. Please note that depending on the number of subjects, electrodes and data points, the computation might take several minutes.

Results of the permutation test will be displayed optimized for the data type in the Main Window and the Detail Windows (see following chapters 15, 16, 17 and 18 for details).



**Figure 2** Visualization of significant data clusters obtained by permutation statistics

Permutation results are data clusters that are now associated with a specific p-value. Up to 100 data clusters are listed. Significant clusters are labeled with stars in the first column of the permutation results:

### One-tailed t-tests

\*\*\*: p-values < 0.001

\*\* : p-values < 0.01 and ≥ 0.001

\* : p-values < 0.05 and ≥ 0.01

+ : p-values < 0.1 and ≥ 0.05

### Two-tailed t-Tests

\*\*\*: p-values < 0.0005

\*\* : p-values < 0.005 and ≥ 0.0005

\* : p-values < 0.025 and ≥ 0.005

+ : p-values < 0.05 and ≥ 0.025

### Permutation Test Results

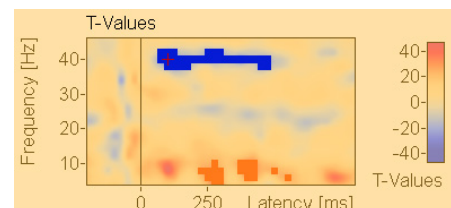
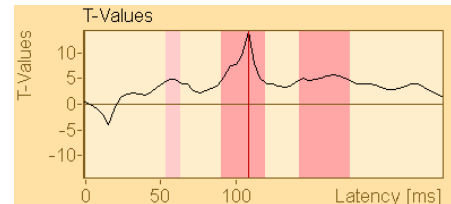
Val	Cluster	+/-	Vis
★★★★	001 [p=0.00000]	+	✓
★★★★	002 [p=0.01000]	+	✓
★★★★	003 [p=0.01000]	+	✓
★★★★	004 [p=0.01000]	+	✓
★★★★	005 [p=0.02000]	+	✓
★★★★	006 [p=0.03000]	+	✓
★★★★	007 [p=0.06000]	+	✓
★★★★	008 [p=0.06000]	+	✓
★★★★	009 [p=0.09000]	+	✓
★★★★	010 [p=0.20000]	-	✓

If there is more than one cluster in the same category, clusters will have a different color to make them distinguishable.

Clusters can be positive or negative (see 8.2) and are accordingly labeled “+” or “-” in the third column of the permutation results.

Clusters can be selected to be visualized in the Main Window by setting a green tick-mark in the fourth column of the permutation results. Only selected clusters will be displayed.

Positive clusters (see 8.2) are marked by light red bars (ERP /ERF, image, SWF) or voxel masks (TFC). Negative clusters are marked by light blue bars or voxel masks (TFC) in the Detail Windows. The **currently selected** cluster is colored dark red or dark blue.



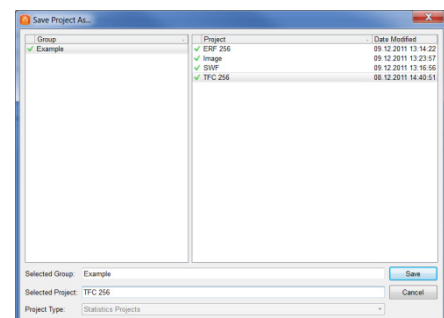
The remaining settings in the Interaction Window are analogue to the previous workstep (Set Parameters, Preliminary t-Test) with the difference that “Mask” now only refers to clusters selected to be visualized.

Press **Finish** to save the project.

You will be prompted to specify a Group and Project name.

Projects with all workflows completed and saved will be marked with a green arrow.

Completed, but not finished projects are marked by a green dot. Incomplete projects are marked by a red dot.



## 15. Analyzing ERP / ERF data

Start BESA Statistics and press **Start new Project**.

### 15.1. Set Project Targets

In the Interaction Window please select **ERP / ERF** and the type of data that will be analyzed. It is possible to load EEG, MEG, intra-cranial (ICR) and polygraphic data (POL).

EEG and MEG data should be associated with a channel position file (\*.elp, see 14.3.1) so that BESA Statistics can display the channels at their correct position and also retrieve the correct neighborhood information for spatial clustering. ICR and POL data are **not** associated with a channel position file and no spatial clustering will be computed.

In the following, MEG data will be used as an example.

Select data type for which statistics shall be performed

- ☐ TFC
- ☐ Image
- ☐ SWF
- ☒ ERP / ERF
  - ☐ EEG
  - ☒ MEG
  - ☐ ICR
  - ☐ POL

In the Interaction Window, please select the type of statistical test to be used for preliminary statistics.

In the following a paired, two-tailed t-test will be used as an example.

Select statistical test

- ☒ T-Test
  - ☒ Paired T-Test
    - ☒ Two-tailed
    - ☐ One-tailed-left
    - ☐ One-tailed-right
  - ☐ Unpaired T-Test

Hit the space-bar or press **Next**.

### 15.2. Load Data

Press **Load Data for Condition 1** in the Interaction Window.

Load Data for Condition 1

Load Data for Condition 2

Specify the design of the experiment. In case a paired t-test was selected, the group name cannot differ between condition 1 and condition 2. In case an unpaired t-test was selected, the condition name cannot differ between group 1 and group 2.

In the following example, "Group" will be called Controls, the first "Condition" will be called Cond. 1.

Press **OK**.

Specify Design

Set name for group and condition.

Group: Controls

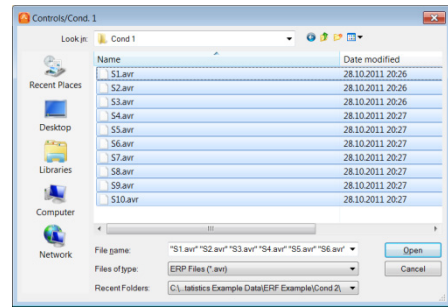
Condition: Cond. 1

OK Cancel

Please browse to the data folder and select the \*.avr files (see 14.3.1) for the first group / condition.

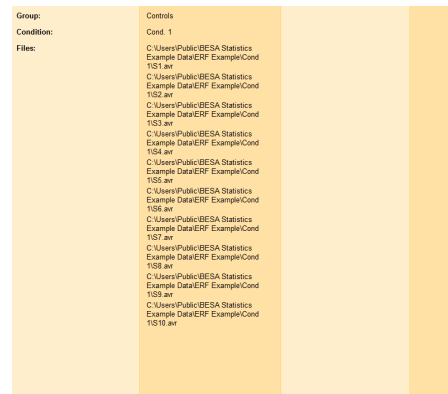
**Please note that in case EEG or MEG data are analyzed, one of the folders must contain a channel position file (\*.elp, see 14.3.1).**

After selecting all desired files press **Open**.



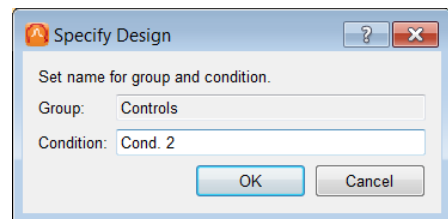
The files loaded in the first step are listed in the Main Window.

Proceed by pressing the space bar, selecting **Load Data for Condition 2** or clicking on **Next**.



Please specify the name of the second condition. Please note that the group name is greyed and cannot be altered because a paired t-test was selected in step 15.1. Had an unpaired t-test been selected, "Condition" would be greyed and the group name could be edited.

Press **OK**.

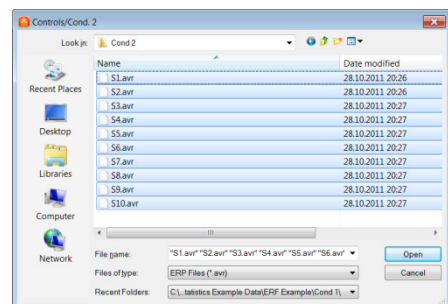


Browse to the folder that contains data for condition 2 and select all desired files.

Please note that in case a paired t-test was selected, the number and order of files constituting both conditions needs to be the same (see

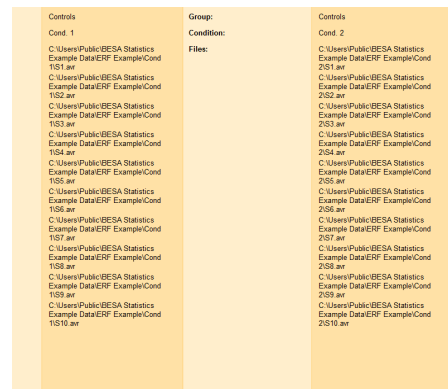
Box 2 Data Organization for paired t-tests).

Press **Open**.



The files loaded in the second step are now also listed in the Main Window.

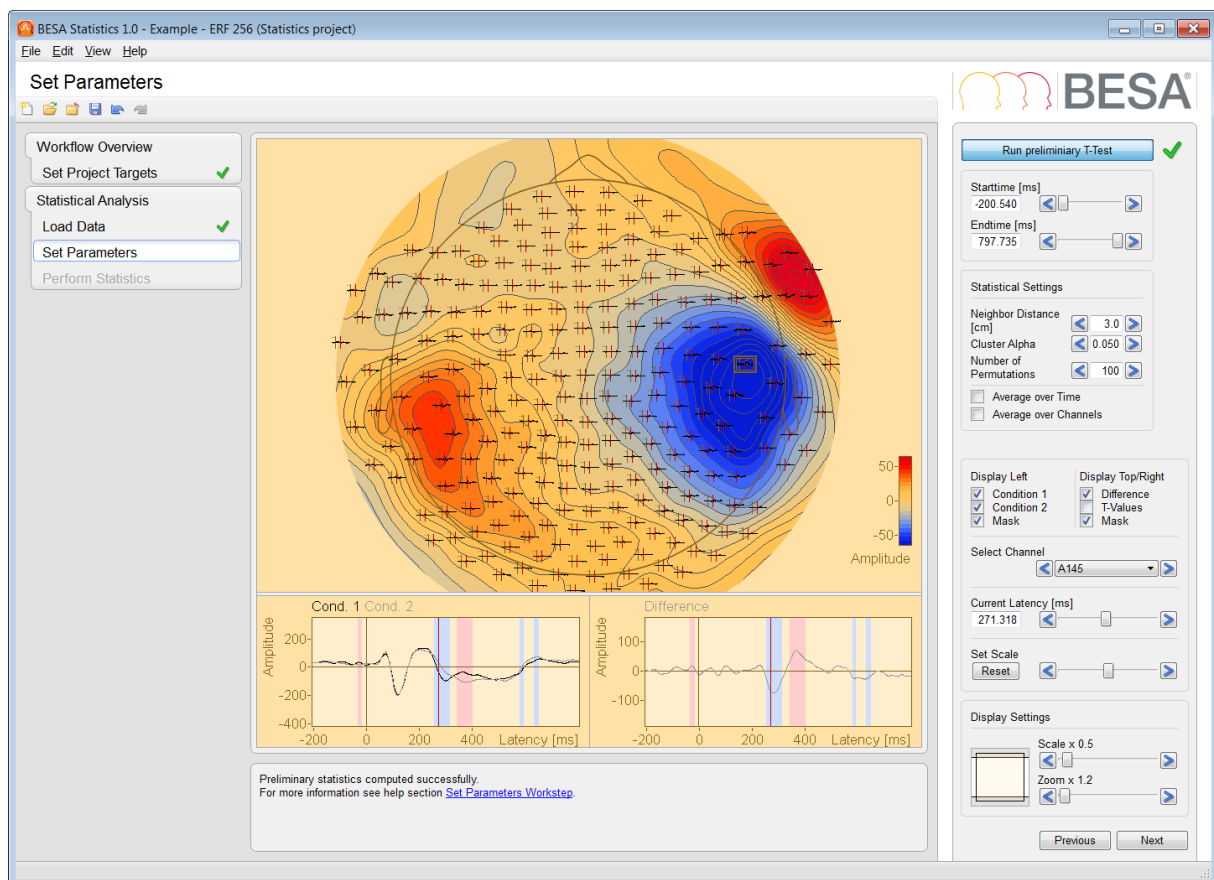
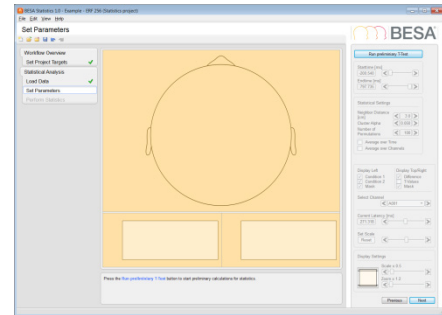
Proceed by pressing the space bar or clicking on **Next**.



### 15.3. Set Parameters

The Set Parameter workstep opens.

Please select **Run preliminary t-Test**, press the space bar or click on **Next**.



Once preliminary statistics are computed, please select an electrode of interest by either left-clicking on it in the Main Window or by using the **Select Channel** drop down box in the Interaction Window. The selected channel is marked by a frame. Please note that you can quickly browse through the channels using the arrow buttons left and right of the Select Channel drop-down box. The selected channel will be displayed in the left and right Detail Windows.

Please set the cursor at a time-point of interest by entering a latency (in ms), dragging the **Current Latency** slider or using the left and right arrow buttons next to the slider in the Interaction Window.

**Display Left** in the Interaction Window defines what is being displayed in the left Detail Window. By default, **Group / Condition 1** and **Group / Condition 2** will be displayed along with a **Mask** indicating significant time periods. Time-ranges, during which group / condition 1 has smaller values than condition 2 are displayed in blue. Time-ranges, during which group / condition 1 has larger values than condition 2 are displayed in red. If desired, the mask as well as each of the groups / conditions can be switched off by un-checking the tick-mark in the according selector boxes.

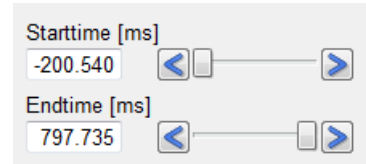
**Display Top/Right** in the Interaction Window determines what will be displayed in the right Detail

Window and the Main Window. A selection can be made between **Difference**, i.e. the difference between groups / conditions or the according **T-Values**. Depending on the selection, a topographic map of the Difference or the t-values will be displayed in the background of the waveforms per channel in the main window. It is also possible to display the **Mask** of significant time-periods in the right Detail Window analogue to the left Detail Window.

Please see chapter 14.4.2 for more details on display settings.

If desired, the **Starttime** and **Endtime** can be adjusted.

In the current example the whole time-range from -200 to 800 ms will be used.



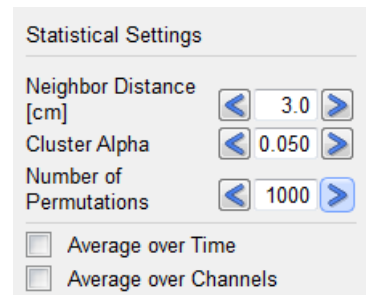
Starttime [ms]  
-200.540

Endtime [ms]  
797.735

Please adjust the **Neighbor Distance** according to your channel layout. In the current example, 3 cm will be used.

If desired, the **Cluster Alpha** value can be adjusted. The default value is 0.05. This will be used in the current example.

If desired, the **Number of Permutations** can be adjusted. The default setting is 1000. This will be used in the current example.



Statistical Settings

Neighbor Distance [cm] 3.0

Cluster Alpha 0.050

Number of Permutations 1000

☐ Average over Time

☐ Average over Channels

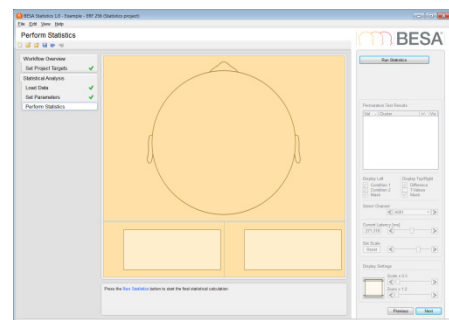
In the current examples, **Average over Time** and **Average over Channels** will not be used.

Please see chapter 14.4.2 for more details on statistical settings.

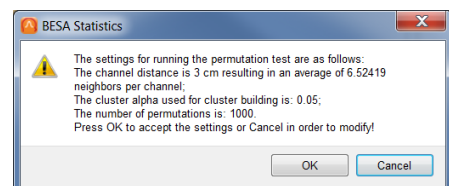
Press **Next** or hit the space bar to proceed to the next workstep.

## 15.4. Perform Statistics

Hit **Run Statistics**, press the space bar or press **Next** to start the permutation statistics.



A window will appear showing the summary of the Statistical Settings as defined in step 15.3. As can be seen in the current example, an average of 6.5 neighbors is found when using a neighbor distance of 3 cm. This is a good estimation of the actual number of neighbors in the channel layout.

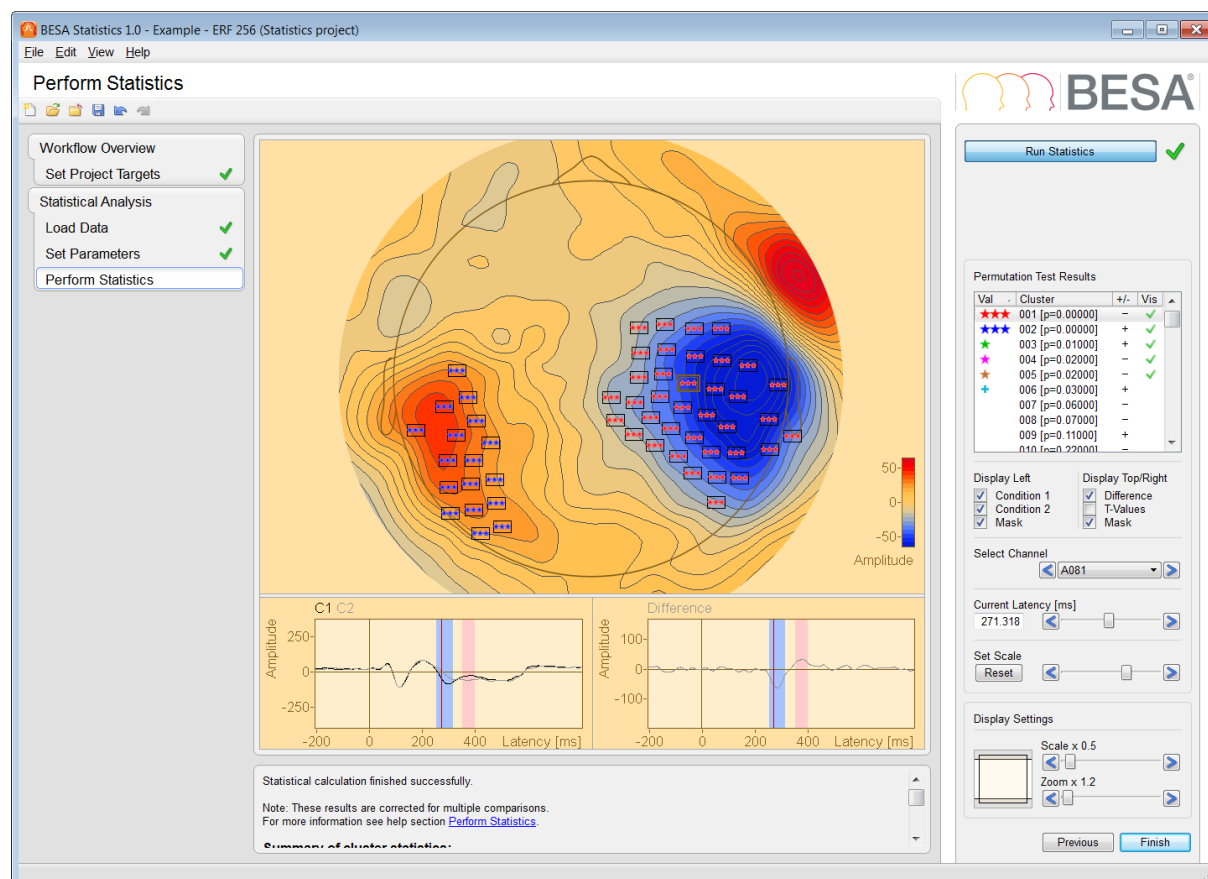
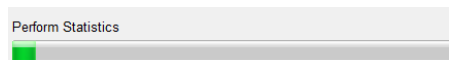


Pressing **OK** will start the permutation statistics. **Cancel** will allow moving back to Set Parameters by pressing **Previous** in the Interaction Window or by selecting **Set Parameters** in the Workflow Window.



Press **OK** to start the permutation statistics.

The Information Window will display the progress of the permutation statistics. Please note that it can take several minutes to complete the calculations depending on the number of subjects, the number of channels and sampling points.



The permutation test results in the current example are 5 significant clusters (see 8.2) and 1 cluster only being significant on a trend level. By default, BESA Statistics automatically selects the most significant cluster and visualizes the data of the channel with the largest absolute t-value in the Detail Windows.

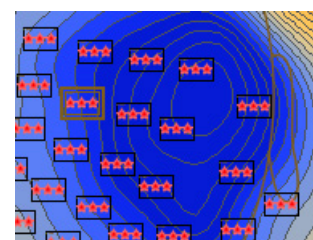
You may browse through the clusters to see their location and time-course.

The most significant cluster is negative, i.e. condition 1 has smaller values than condition 2 in an extended data cluster over the right temporal area.

All channels belonging to a cluster are labeled by the same color.

See more details on cluster visualization in chapter 14.5.

Val	Cluster	+/-	Vis
★★★	001 [p=0.00000]	-	✓
★★★	002 [p=0.00000]	+	✓
★	003 [p=0.01000]	+	✓
★	004 [p=0.02000]	-	✓
★	005 [p=0.02000]	-	✓
+	006 [p=0.03000]	+	
	007 [p=0.06000]	-	
	008 [p=0.07000]	-	
	009 [p=0.11000]	+	
	010 [p=0.22000]	-	



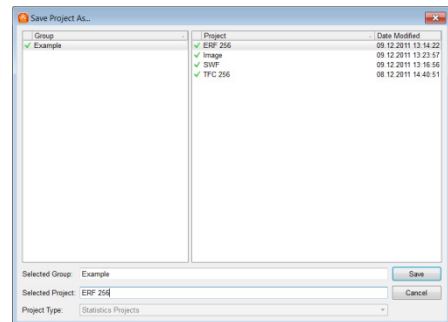
Information on all significant clusters is summarized in the Information Window. The following information is given:

- cluster number
- cluster p-value
- mean of group / condition 1
- mean of group / condition 2.

Clusters	p-values	Mean 1	Mean 2
Cluster 1	0	-36.2797	2.1105
Cluster 2	0	45.3171	13.959

Click on **Finish** to save and close the project.

Please enter a **Group** and **Project** name. The project can be re-loaded at any time (see 9). All previous worksteps are saved and can be re-visited without repeat calculations.





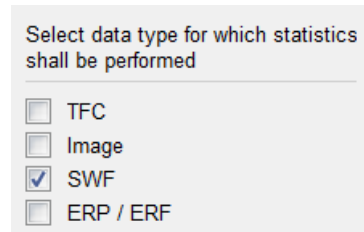
## 16. Analyzing Source Waveforms

Start BESA Statistics and press [Start new Project](#).

### 16.1. Set Project Targets

In the Interaction Window please select **SWF** (source waveforms)

SWF data should be associated with a source position file (\*.bsa, see 14.3.1) so that BESA Statistics can display the sources at their correct position.

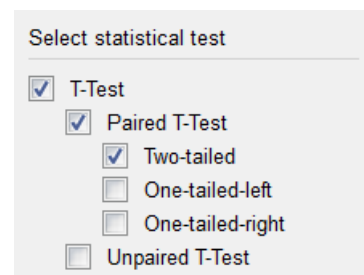


Select data type for which statistics shall be performed

- ☐ TFC
- ☐ Image
- ☒ SWF
- ☐ ERP / ERF

In the Interaction Window, please select the type of statistical test to be used for preliminary statistics.

In the following a paired, two-tailed t-test will be used as an example.



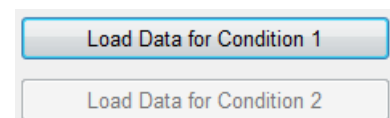
Select statistical test

- ☒ T-Test
  - ☒ Paired T-Test
    - ☒ Two-tailed
    - ☐ One-tailed-left
    - ☐ One-tailed-right
  - ☐ Unpaired T-Test

Hit the space-bar or press [Next](#).

### 16.2. Load Data

Press [Load Data for Condition 1](#) in the Interaction Window.



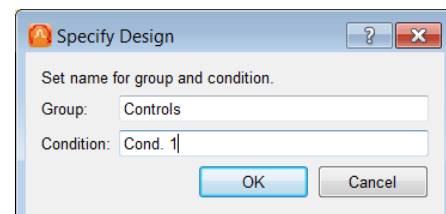
Load Data for Condition 1

Load Data for Condition 2

Specify the design of the experiment. In case a paired t-test was selected, the group name cannot differ between condition 1 and condition 2. In case an unpaired t-test was selected, the condition name cannot differ between group 1 and group 2.

In the following example, "Group" will be called Controls, the first "Condition" will be called Cond. 1.

Press [OK](#).



Specify Design

Set name for group and condition.

Group: Controls

Condition: Cond. 1

OK Cancel

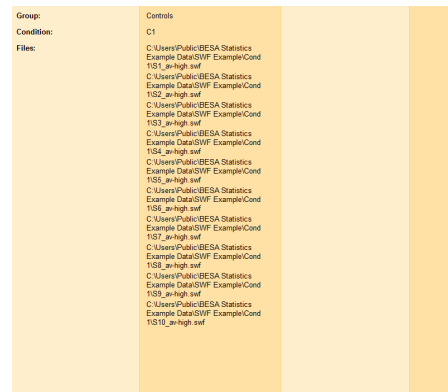
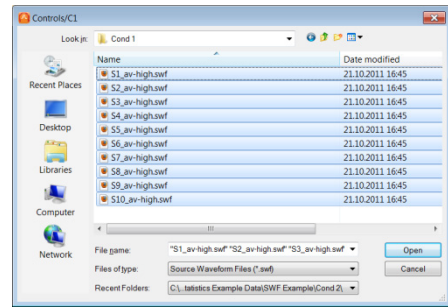
Please browse to the data folder and select the \*.swf files for the first group / condition (see 14.3.1).

**Please note that when SWF data are analyzed, one of the folders must contain a source position file (\*.bsa, see 14.3.1).**

After selecting all desired files press **Open**.

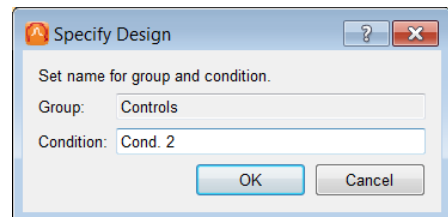
The files loaded in the first step are listed in the Main Window.

Proceed by pressing the space bar, selecting **Load Data for Condition 2** or clicking on **Next**.



Please specify the name of the second condition. Please note that the group name is greyed and cannot be altered because a paired t-test was selected in step 16.1. Had an unpaired t-test been selected, "Condition" would be greyed and the group name could be edited.

Press **OK**.

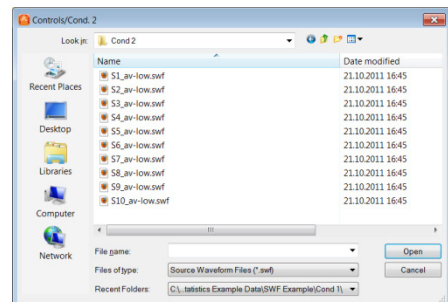


Browse to the folder that contains data for condition 2 and select all desired files.

Please note that in case a paired t-test was selected, the number and order of files constituting both conditions needs to be the same (see

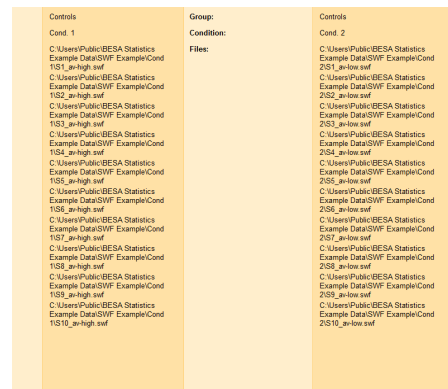
Box 2 Data Organization for paired t-tests).

Press **Open**.



The files loaded in the second step are now also listed in the Main Window.

Proceed by pressing the space bar or clicking on **Next**.

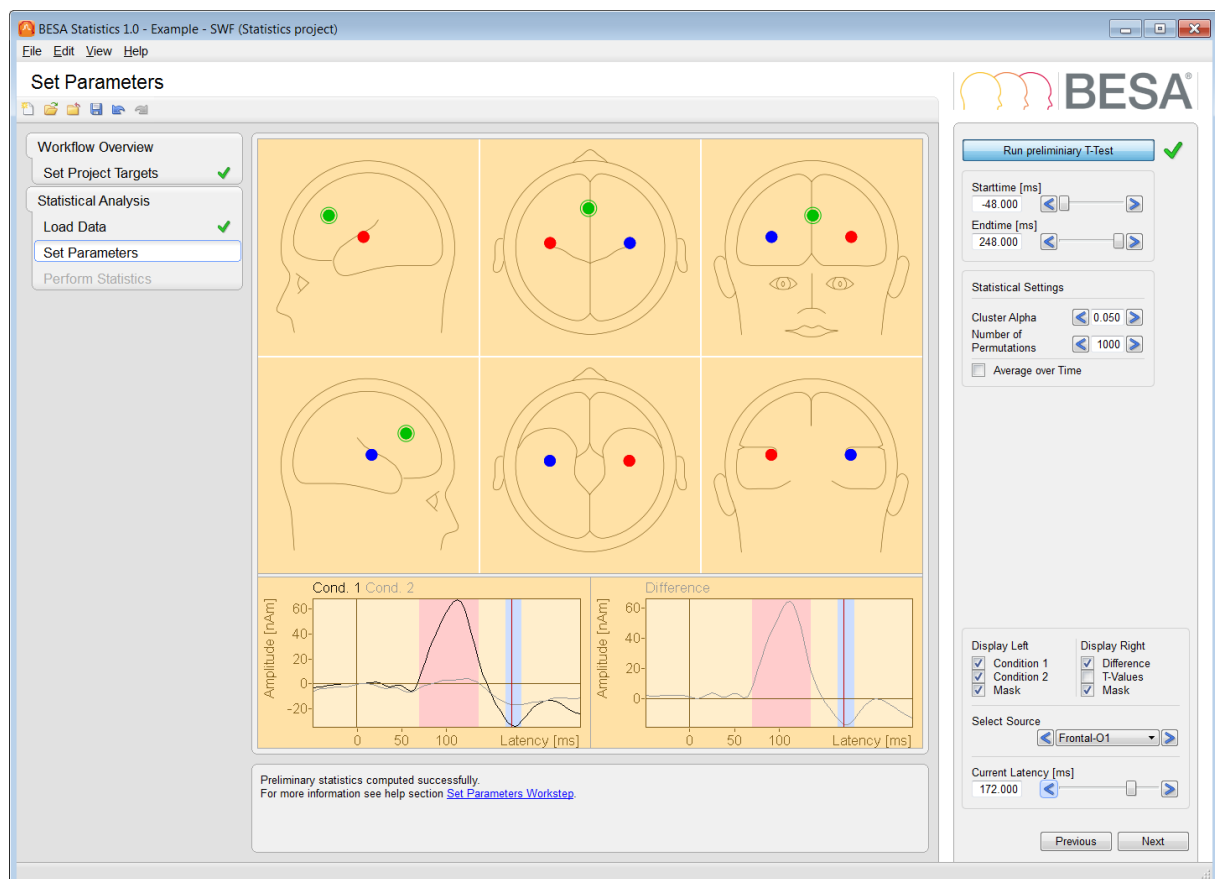
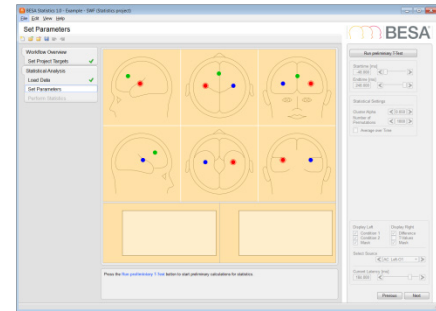


## 16.3. Set Parameters

The Set Parameter workstep opens.

The sources found in the source position file (\*.bsa, , see 14.3.1) will be displayed.

Please select **Run preliminary t-Test**, press the space bar or click on **Next**.



Once preliminary statistics are computed, please select a source of interest by either left-clicking on it in the Main Window or by using the **Select Source** drop down box in the Interaction Window. In case regional sources are analyzed, left-clicking on a source in the Main Window will select the first orientation of the selected source by default. Other orientations can be chosen in the Select Source drop-down box. Orientations are indicated by “-O1”, “-O2” or “-O3” following the source label. The selected source is highlighted by a circle. Please note that you can quickly browse through the sources using the arrow buttons left and right of the Select Source drop-down box. The source waveforms of the selected source will be displayed in the left and right Detail Windows.

Please set the cursor at a time-point of interest by entering a latency (in ms), dragging the **Current Latency** slider or using the left and right arrow buttons next to the slider in the Interaction Window.

**Display Left** in the Interaction Window defines what is being displayed in the left Detail Window. By default, **Group / Condition 1** and **Group / Condition 2** will be displayed along with a **Mask** indicating significant time periods. Time-ranges, during which group / condition 1 has smaller values than condition 2 are displayed in blue. Time-ranges, during which group / condition 1 has larger values than condition 2 are displayed in red. If desired, the mask as well as each of the groups / conditions can be

switched off by un-checking the tick-mark in the according selector boxes.

**Display Right** in the Interaction Window determines what will be displayed in the right Detail Window. A selection can be made between **Difference**, i.e. the difference between groups / conditions or the according **T-Values**. It is also possible to display the **Mask** of significant time-periods in the right Detail Window analogue to the left Detail Window.

Please see chapter 14.4.2 for more details on display settings.

If desired, the **Starttime** and **Endtime** can be adjusted.

In the current example the whole time-range from -50 to 250 ms will be used.

Starttime [ms]  
-48.000

Endtime [ms]  
248.000

Please note that **it is not possible to specify a Neighbor Distance for SWF data**. The reason is that single dipoles and regional sources are discrete, i.e. they represent separate brain regions differing from each other in their activity pattern. Clustering them in space would destroy the advantageous property of discrete sources to separate brain regions.

Statistical Settings

Cluster Alpha

Number of Permutations

☐ Average over Time

If desired, the **Cluster Alpha** value can be adjusted. The default value is 0.05. This will be used in the current example.

If desired, the **Number of Permutations** can be adjusted. The default setting is 1000. This will be used in the current example.

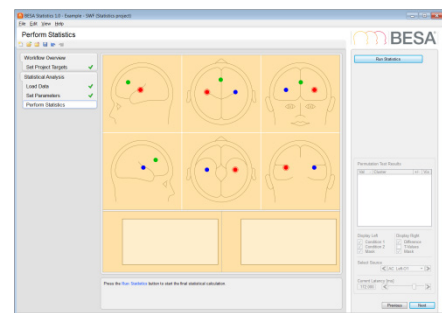
In the current example, **Average over Time** will not be used. Average over Channels is not available for the same reason as described above: averaging sources would destroy the advantageous property of discrete sources to separate brain regions.

Please see chapter 14.4.2 for more details on statistical settings.

Press **Next** or hit the space bar to proceed to the next workstep.

## 16.4. Perform Statistics

Hit **Run Statistics**, press the space bar or press **Next** to start the permutation statistics.

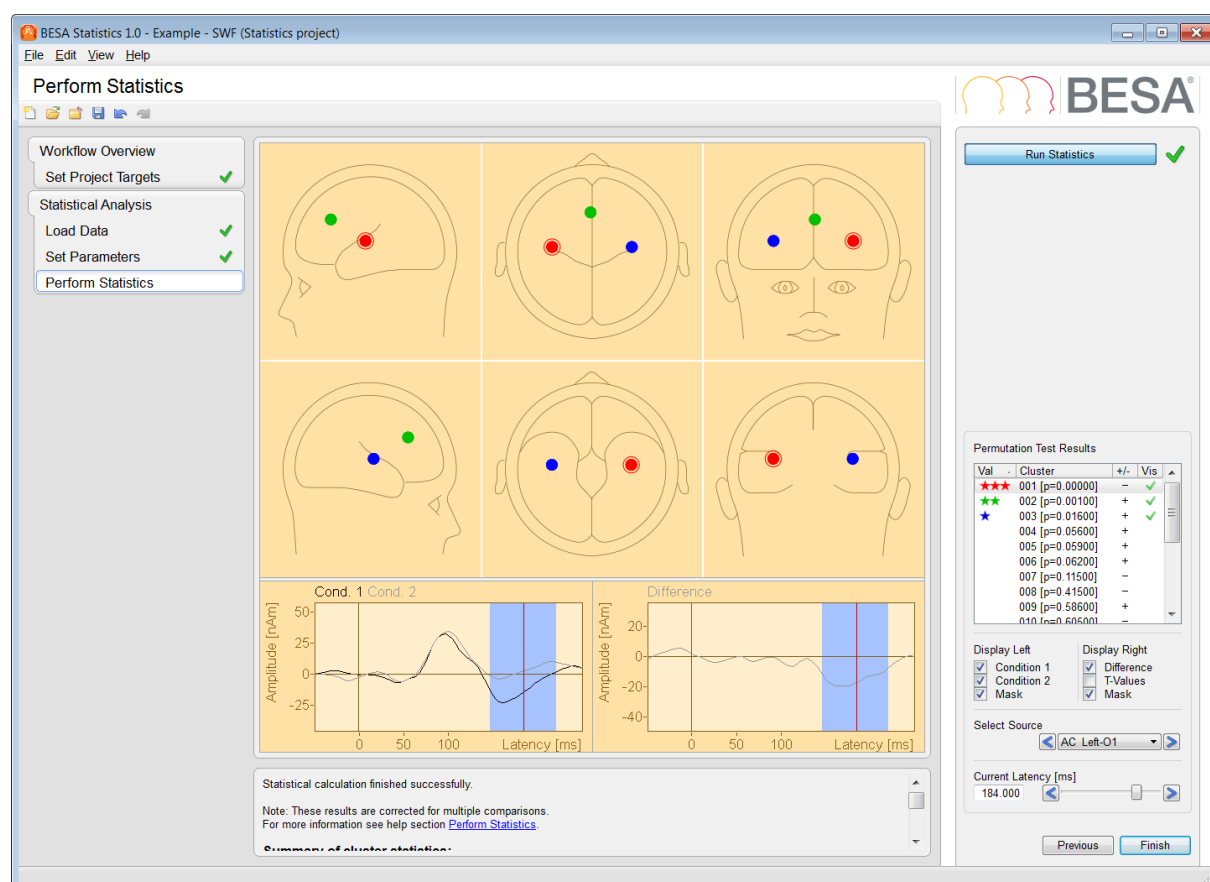
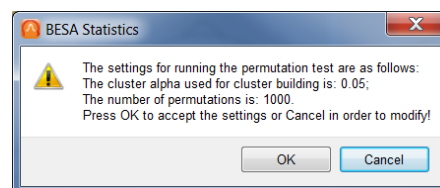


A window will appear showing the summary of the Statistical Settings as defined in step 16.3.

Pressing **OK** will start the permutation statistics. **Cancel** will allow moving back to Set Parameters by pressing **Previous** in the Interaction Window or by selecting **Set Parameters** in the Workflow Window.

Press **OK** to start the permutation statistics.

The Information Window will display the progress of the permutation statistics. Please note that it can take several minutes to complete the calculations depending on the number of subjects, the number of sources and sampling points.



The permutation test results in the current example are 3 significant clusters (see 8.2). By default, BESA Statistics automatically selects the most significant cluster and visualizes the data of the source with the largest absolute t-value in the Detail Windows.

You may browse through the clusters to see their time-course at the corresponding source.

In the present example the most significant cluster is found in the first orientation of the left temporal source. The cluster is negative, indicating that condition 1 has smaller values than condition 2.

Permutation Test Results

Val	Cluster	+/-	Vis
★★★	001 [p=0.00000]	-	✓
★★	002 [p=0.00100]	+	✓
★	003 [p=0.01600]	+	✓
	004 [p=0.05600]	+	
	005 [p=0.05900]	+	
	006 [p=0.06200]	+	
	007 [p=0.11500]	-	
	008 [p=0.41500]	-	
	009 [p=0.58600]	+	
	010 [p=0.60500]	-	

The clusters are highlighted in the Detail Windows if the Mask box is ticked.

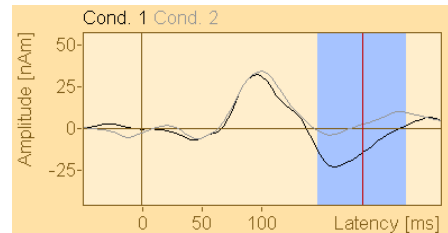
See more details on cluster visualization in chapter 14.5.

Information on all significant clusters is summarized in the Information Window. The following information is given:

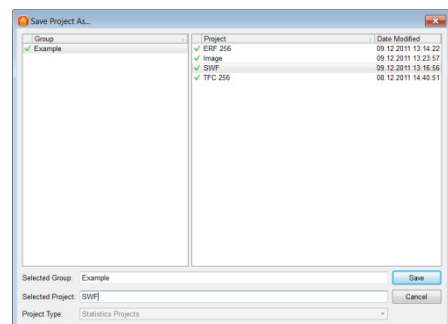
- cluster number
- cluster p-value
- mean of group / condition 1
- mean of group / condition 2.

Click on **Finish** to save and close the project.

Please enter a **Group** and **Project** name. The project can be re-loaded at any time (see 9). All previous worksteps are saved and can be re-visited without repeat calculations.



Clusters	p-values	Mean 1	Mean 2
Cluster 1	0	-13.0606	2.44677
Cluster 2	0.001	45.5094	1.7357



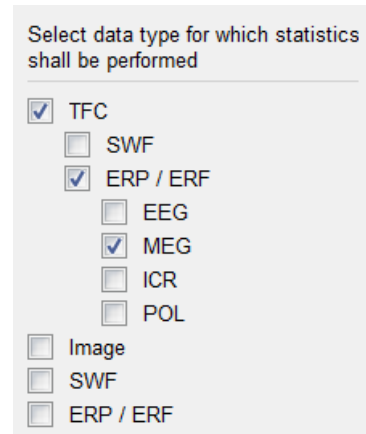
## 17. Analyzing Time Frequency Data

Start BESA Statistics and press [Start new Project](#).

### 17.1. Set Project Targets

In the Interaction Window please select **TFC** and the type of data that will be analyzed. It is possible to analyze TFC results based on source montages (SWF) or channels in sensor space (ERP / ERF). If the latter is selected, it must be chosen between EEG, MEG, intra-cranial (ICR) and polygraphic data (POL).

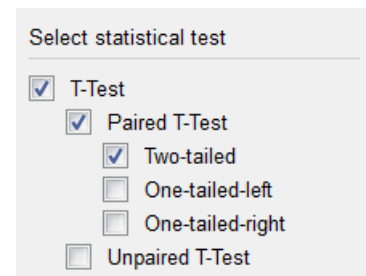
**TFC analysis based on ERP / ERF EEG and MEG data should be associated with a channel position file (\*.elp, see 14.3.1)** so that BESA Statistics can display the channels at their correct position and also retrieve the correct neighborhood information for spatial clustering. ICR and POL data are **not** associated with a channel position file and no spatial clustering will be computed. **TFC analysis based on source montages (SWF) should be associated with a source position file (\*.bsa, see 14.3.1)** so that BESA Statistics can display the sources at their correct position.



In the following, TFC ERP /ERF MEG data will be used as an example.

In the Interaction Window, please select the type of statistical test to be used for preliminary statistics.

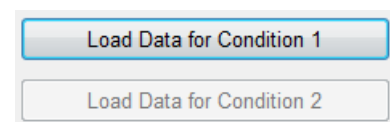
In the following a paired, two-tailed t-test will be used as an example.



Hit the space-bar or press [Next](#).

### 17.2. Load Data

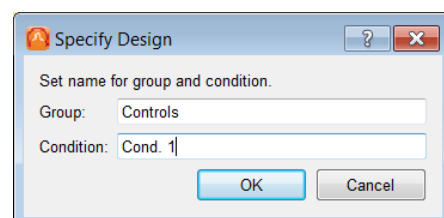
Press [Load Data for Condition 1](#) in the Interaction Window.



Specify the design of the experiment. In case a paired t-test was selected, the group name cannot differ between condition 1 and condition 2. In case an unpaired t-test was selected, the condition name cannot differ between group 1 and group 2.

In the following example, “Group” will be called Controls, the first “Condition” will be called Cond. 1.

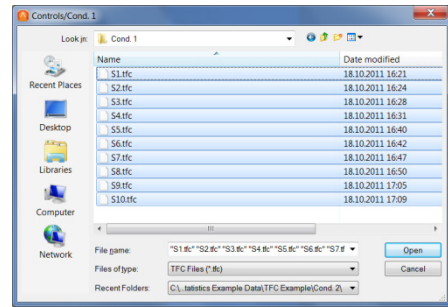
Press [OK](#).



Please browse to the data folder and select the \*.tfc files (see 14.3.1) for the first group / condition.

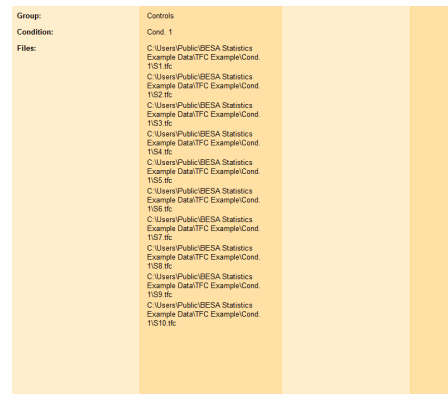
**Please note that in sensor data are analyzed, one of the folders must contain a channel position file (\*.elp, see 14.3.1).**

After selecting all desired files press **Open**.



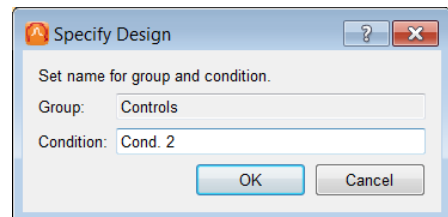
The files loaded in the first step are listed in the Main Window.

Proceed by pressing the space bar, selecting **Load Data for Condition 2** or clicking on **Next**.



Please specify the name of the second condition. Please note that the group name is greyed and cannot be altered because a paired t-test was selected in step 17.1. Had an unpaired t-test been selected, "Condition" would be greyed and the group name could be edited.

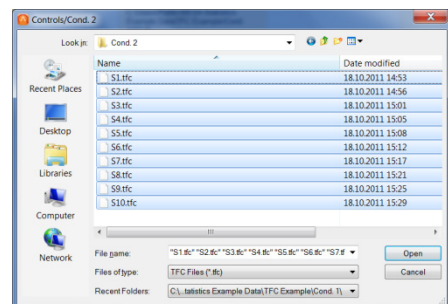
Press **OK**.



Browse to the folder that contains data for condition 2 and select all desired files.

Please note that in case a paired t-test was selected, the number and order of files constituting both conditions needs to be the same (see

Box 2 Data Organization for paired t-tests).



Press **Open**.



The files loaded in the second step are now also listed in the Main Window.

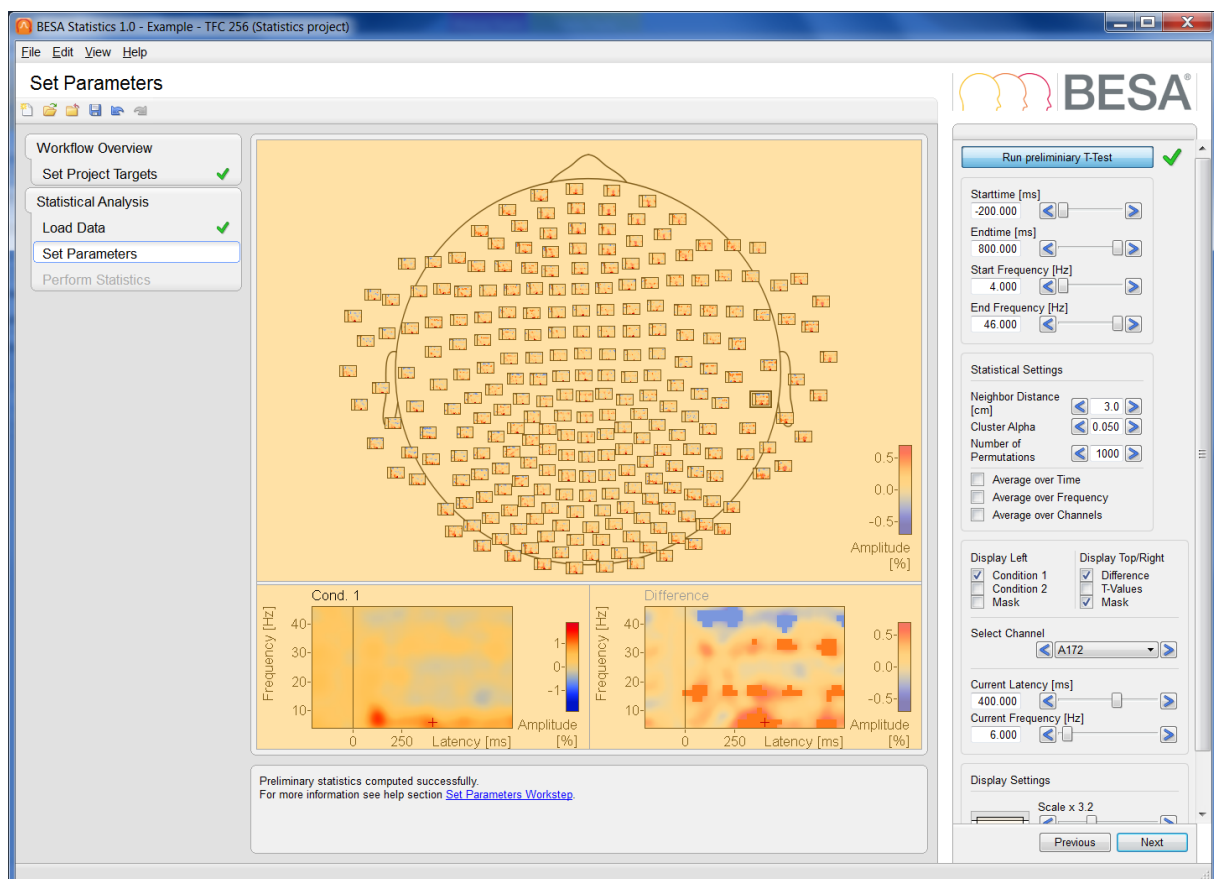
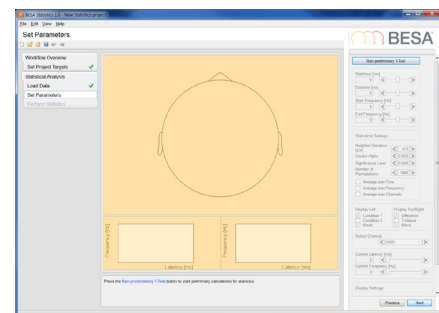
Proceed by pressing the space bar or clicking on **Next**.

Controls	Group:	Controls
Cond 1	Condition:	Cond 2
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\51.8c	Files:	C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\51.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\52.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\52.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\53.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\53.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\54.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\54.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\55.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\55.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\56.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\56.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\57.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\57.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\58.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\58.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\59.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\59.8c
C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 1\60.8c		C:\Users\Public\BESA Statistics Example Data\TFC Example\Cond 2\60.8c

## 17.3. Set Parameters

The Set Parameter workstep opens.

Please select **Run preliminary t-Test**, press the space bar or click on **Next**.



Once preliminary statistics are computed, please select an electrode of interest by either left-clicking

on it in the Main Window or by using the **Select Channel** drop down box in the Interaction Window. The selected channel is marked by a frame. Please note that you can quickly browse through the channels using the arrow buttons left and right of the Select Channel drop-down box. The selected channel will be displayed in the left and right Detail Windows.

A crosshair can be placed at a time-frequency point of interest by entering a latency (in ms) / frequency (in Hz), dragging the **Current Latency** / **Current Frequency** slider or using the left and right arrow buttons next to the sliders in the Interaction Window.

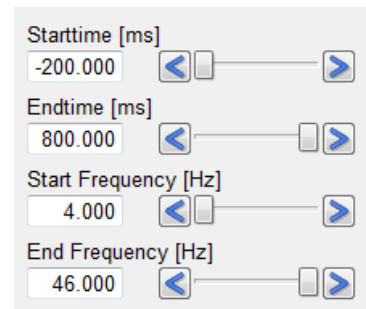
**Display Left** in the Interaction Window defines what is being displayed in the left Detail Window. By default, **Group / Condition 1** and **Group / Condition 2** will be displayed along with a **Mask** indicating significant time periods. Time-frequency ranges, during which group / condition 1 has smaller values than condition 2 are displayed in blue. Time-frequency ranges, during which group / condition 1 has larger values than condition 2 are displayed in red. If desired, the mask as well as each of the groups / conditions can be switched off by un-checking the tick-mark in the according selector boxes.

**Display Top/Right** in the Interaction Window determines what will be displayed in the right Detail Window and the Main Window. A selection can be made between **Difference**, i.e. the difference between groups / conditions or the according **T-Values**. It is also possible to display the **Mask** of significant time-periods in the right Detail Window analogue to the left Detail Window.

Please see chapter 14.4.2 for more details on display settings.

If desired, the **Starttime** / **Start Frequency** and **Endtime** / **End Frequency** can be adjusted.

In the current example the whole time-range from -200 to 800 ms and frequency range from 4 to 46 Hz will be used.



Starttime [ms]  
-200.000

Endtime [ms]  
800.000

Start Frequency [Hz]  
4.000

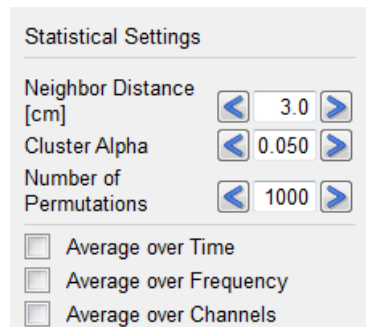
End Frequency [Hz]  
46.000

Please adjust the **Neighbor Distance** according to your channel layout. In the current example, 3 cm will be used.

If desired, the **Cluster Alpha** value can be adjusted. The default value is 0.05. This will be used in the current example.

If desired, the **Number of Permutations** can be adjusted. The default setting is 1000. This will be used in the current example.

In the current examples, **Average over Time**, **Average over Channels** and **Average over Frequency** will not be used.



Statistical Settings

Neighbor Distance [cm] 3.0

Cluster Alpha 0.050

Number of Permutations 1000

☐ Average over Time

☐ Average over Frequency

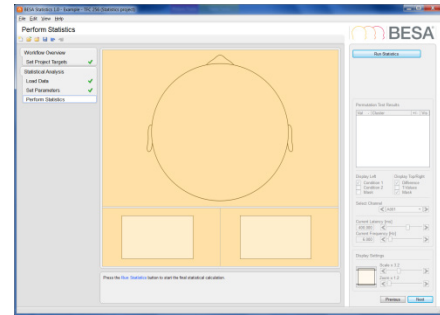
☐ Average over Channels

Please see chapter 14.4.2 for more details on statistical settings.

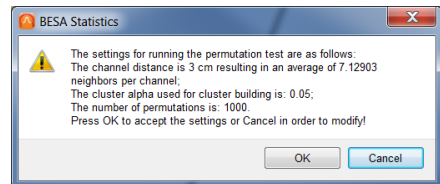
Press **Next** or hit the space bar to proceed to the next workstep.

## 17.4. Perform Statistics

Hit **Run Statistics**, press the space bar or press **Next** to start the permutation statistics.



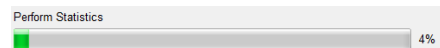
A window will appear showing the summary of the Statistical Settings as defined in step 15.3. As can be seen in the current example, an average of 7 neighbors is found when using a neighbor distance of 3 cm. This is a good estimation of the actual number of neighbors in the channel layout.

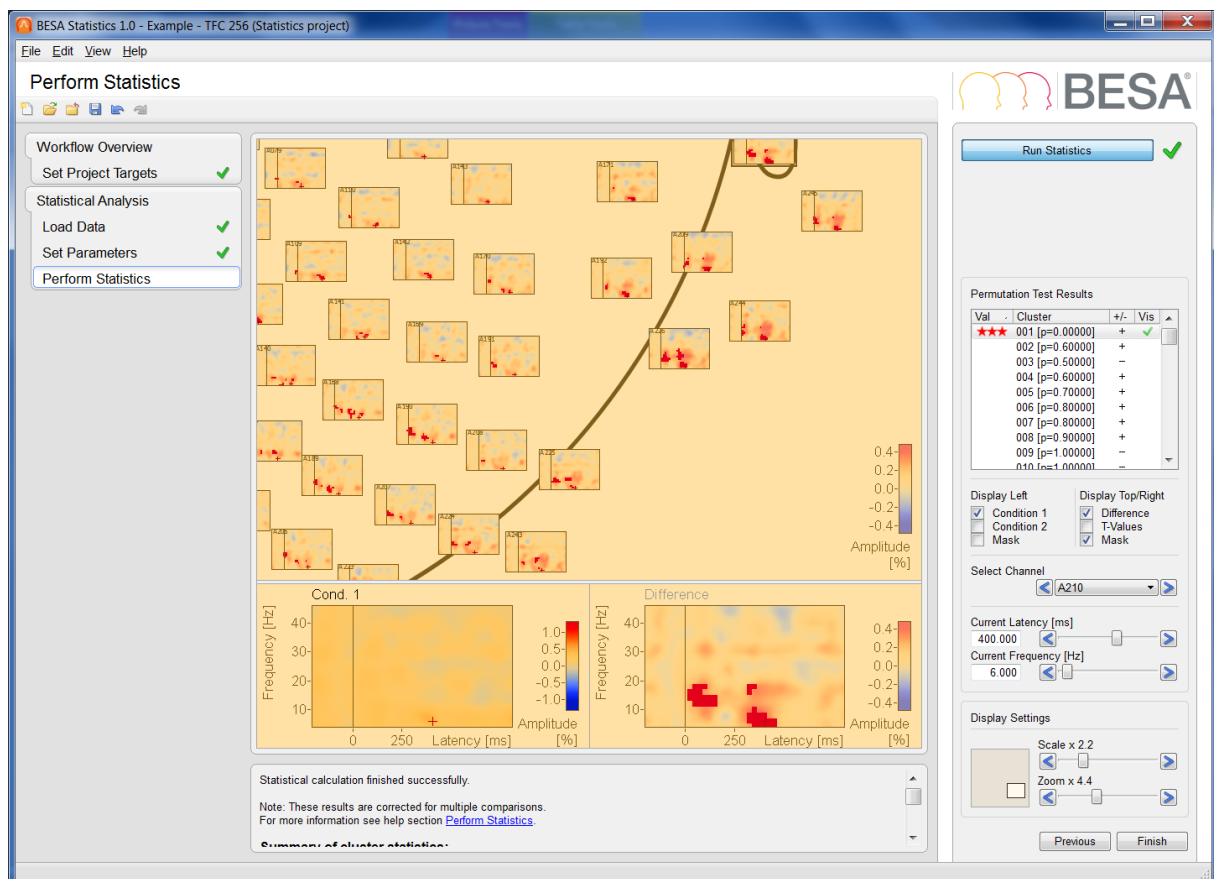


Pressing **OK** will start the permutation statistics. **Cancel** will allow moving back to Set Parameters by pressing **Previous** in the Interaction Window or by selecting **Set Parameters** in the Workflow Window.

Press **OK** to start the permutation statistics.

The Information Window will display the progress of the permutation statistics. Please note that it can take several minutes to complete the calculations depending on the number of subjects, the number of channels and sampling points.





The permutation test result in the current example is 1 significant cluster (see 8.2). By default, BESA Statistics automatically selects the most significant cluster and visualizes the data of the channel with the largest absolute t-value in the Detail Windows.

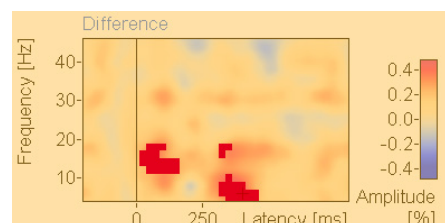
The significant cluster is positive, i.e. condition 1 has larger values than condition 2 over a relatively long period of time (ca. 10 to 500 ms) in right temporo-parietal sensors. The cluster seems dominated by activity in the beta-range earlier on (10 to 150 ms) and activity in the theta-alpha range later on (300 – 500 ms).

Permutation Test Results

Val	Cluster	+/-	Vis
★★★	001 [p=0.00000]	+	✓
	002 [p=0.60000]	+	
	003 [p=0.50000]	-	
	004 [p=0.60000]	+	
	005 [p=0.70000]	+	
	006 [p=0.80000]	+	
	007 [p=0.80000]	+	
	008 [p=0.90000]	+	
	009 [p=1.00000]	-	
	010 [p=1.00000]	-	

All channels belonging to a cluster are overlaid with the according cluster mask, if the mask is displayed.

See more details on cluster visualization in chapter 14.5.



Information on all significant clusters is summarized in the Information Window. The following information is given:

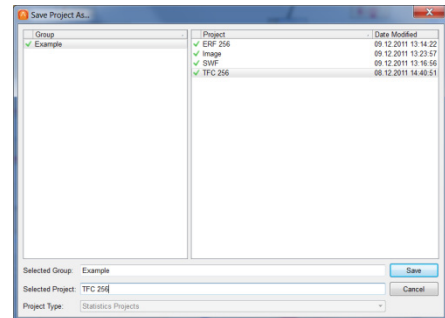
- cluster number
- cluster p-value

Clusters	p-values	Mean 1	Mean 2
Cluster 1	0	0.0581576	-0.0491047
Cluster 2	0.6	0.0307094	-0.0392233

- mean of group / condition 1
- mean of group / condition 2.

Click on **Finish** to save and close the project.

Please enter a **Group** and **Project** name. The project can be re-loaded at any time (see 9). All previous worksteps are saved and can be re-visited without repeat calculations.



## 18. Analyzing Image Data

Start BESA Statistics and press [Start new Project](#).

### 18.1. Set Project Targets

In the Interaction Window please select **Image**.

Select data type for which statistics shall be performed

☐ TFC

☒ Image

☐ SWF

☐ ERP / ERF

In the Interaction Window, please select the type of statistical test to be used for preliminary statistics.

In the following a paired, two-tailed t-test will be used as an example.

Select statistical test

☒ T-Test

☒ Paired T-Test

☒ Two-tailed

☐ One-tailed-left

☐ One-tailed-right

☐ Unpaired T-Test

Hit the space-bar or press [Next](#).

### 18.2. Load Data

Press [Load Data for Condition 1](#) in the Interaction Window.

[Load Data for Condition 1](#)

[Load Data for Condition 2](#)

Specify the design of the experiment. In case a paired t-test was selected, the group name cannot differ between condition 1 and condition 2. In case an unpaired t-test was selected, the condition name cannot differ between group 1 and group 2.

In the following example, the first "Group" will be called Controls, the "Condition" will be called Standard.

Specify Design

Set name for group and condition.

Group: Controls

Condition: Cond. 1

[OK](#) [Cancel](#)

Press [OK](#).

Please browse to the data folder and select the \*.dat files (see 14.3.1) for the first group / condition.

**Please note that the \*.dat files can contain voxel information on 1 time-point or a time-series.**

After selecting all desired files press [Open](#).

Controls/Cond. 1

Look in: Cond 1

Name	Date	Type	Size
S1_av-high.dat	28.10.2011 16:37	DAT File	9.553 I
S2_av-high.dat	28.10.2011 16:37	DAT File	9.553 I
S3_av-high.dat	28.10.2011 16:38	DAT File	9.553 I
S4_av-high.dat	28.10.2011 16:38	DAT File	9.553 I
S5_av-high.dat	28.10.2011 16:38	DAT File	9.553 I
S6_av-high.dat	28.10.2011 16:38	DAT File	9.553 I
S7_av-high.dat	28.10.2011 16:39	DAT File	9.553 I
S8_av-high.dat	28.10.2011 16:39	DAT File	9.553 I
S9_av-high.dat	28.10.2011 16:39	DAT File	9.553 I
S10_av-high.dat	28.10.2011 16:39	DAT File	9.553 I

File name: "S1\_av-high.dat" "S2\_av-high.dat" "S3\_av-high.dat"

Files of type: Image Files (\*.dat)

Recent Folders: D:\\_ta State (a)Image Data Within\_Zeitreihe(Low)

[Open](#) [Cancel](#)

The files loaded in the first step are listed in the Main Window.

Proceed by pressing the space bar, selecting **Load Data for Group 2** or clicking on **Next**.

Group:	Controls
Condition:	Cond. 1
Files:	C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S1_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S2_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S3_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S4_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S5_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S6_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S7_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S8_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S9_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S10_av-high.dat

Please specify the name of the second group. Please note that the condition name is greyed and cannot be altered because an unpaired t-test was selected in step 18.1. Had a paired t-test been selected, "Group" would be greyed and the condition name could be edited.

Press **OK**.

Browse to the folder that contains data for condition 2 and select all desired files.

Please note that as an unpaired t-test was selected, the number and order of files constituting both conditions does not have to be the same (see

Box 2).

Press **Open**.

The files loaded in the second step are now also listed in the Main Window.

Proceed by pressing the space bar or clicking on **Next**.

**Specify Design**

Set name for group and condition.

Group:

Condition:

**OK** **Cancel**

**Controls/Cond. 2**

Look in: Cond 2

Name	Date	Type	Size
S1_av-low.dat	28.10.2011 16:37	DAT File	9.553 KB
S2_av-low.dat	28.10.2011 16:37	DAT File	9.553 KB
S3_av-low.dat	28.10.2011 16:38	DAT File	9.553 KB
S4_av-low.dat	28.10.2011 16:38	DAT File	9.553 KB
S5_av-low.dat	28.10.2011 16:38	DAT File	9.553 KB
S6_av-low.dat	28.10.2011 16:39	DAT File	9.553 KB
S7_av-low.dat	28.10.2011 16:39	DAT File	9.553 KB
S8_av-low.dat	28.10.2011 16:39	DAT File	9.553 KB
S9_av-low.dat	28.10.2011 16:39	DAT File	9.553 KB
S10_av-low.dat	28.10.2011 16:40	DAT File	9.553 KB

File name:

Files of type:

Recent folders:

**Open** **Cancel**

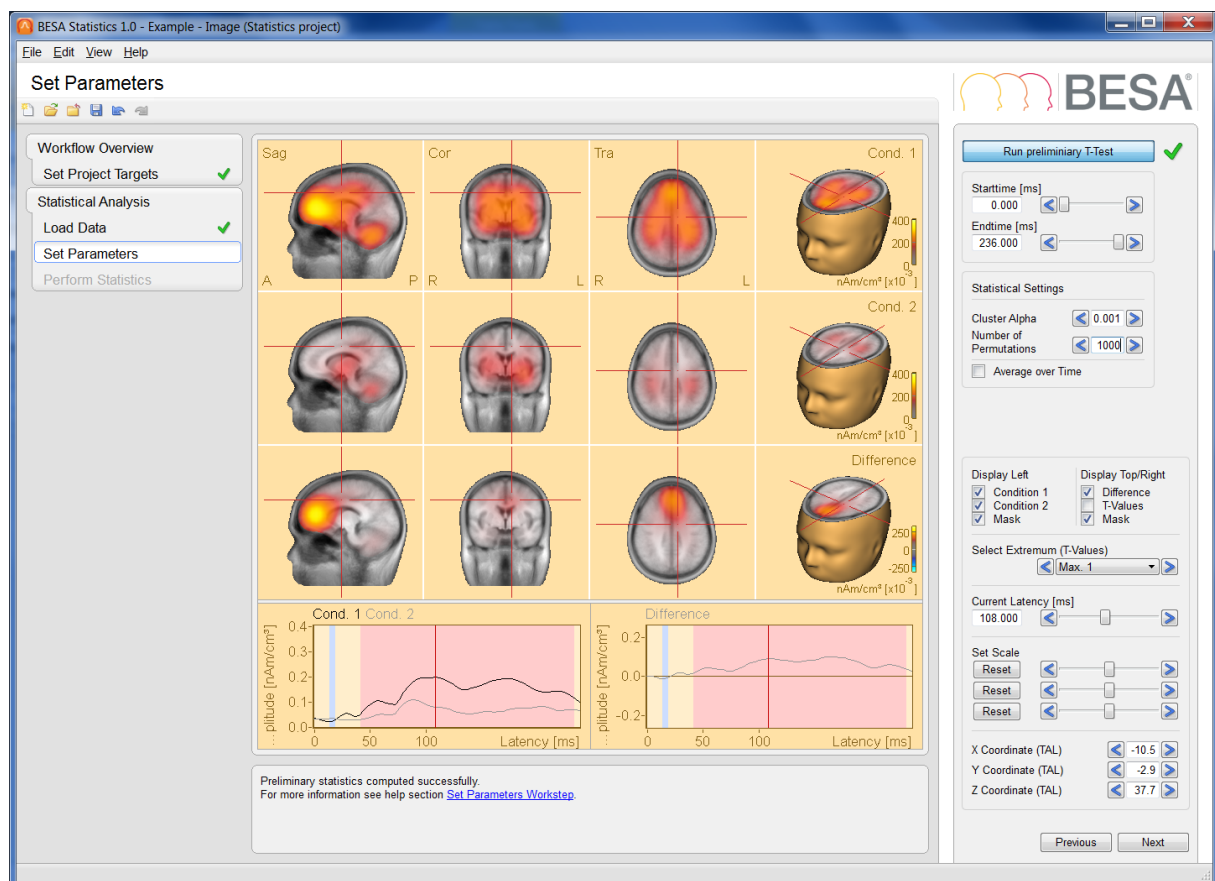
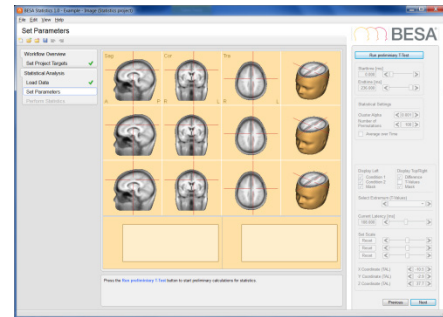
Controls	Group:	Controls
Cond. 1	Condition:	Cond. 2
Files:		
C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S1_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S2_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S3_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S4_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S5_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S6_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S7_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S8_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S9_av-high.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 1\S10_av-high.dat		C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S1_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S2_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S3_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S4_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S5_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S6_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S7_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S8_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S9_av-low.dat C:\Users\Public\BESA Statistics Example Data\image Example\Cond 2\S10_av-low.dat



## 18.3. Set Parameters

The Set Parameter workstep opens.

Please select **Run preliminary t-Test**, press the space bar or click on **Next**.



Line 1 in the Main Window displays activity in Group / Condition 1, line 2 displays activity in Group / Condition 2. Line 3 displays the activation difference between groups / condition or the according t-values, depending on the selection under Display Top/Right (see below).

Once preliminary statistics are computed, please select a voxel of interest by using the **Select Extremum** drop down box in the Interaction Window. The selected voxel is marked by a crosshair. Please note that you can quickly browse through the extrema using the arrow buttons left and right of the Select Extremum drop-down box. The activation time-course of the selected extremum are displayed in the left and right Detail Windows. Additionally, Talairach coordinates of the selected extremum are displayed at the bottom of the Interaction Window.

Please set the cursor at a time-point of interest by entering a latency (in ms), dragging the **Current Latency** slider or using the left and right arrow buttons next to the slider in the Interaction Window.

**Display Left** in the Interaction Window defines what is being displayed in the left Detail Window. By default, **Group / Condition 1** and **Group / Condition 2** will be displayed along with a **Mask** indicating significant time periods. Time-ranges, during which group / condition 1 has smaller values than



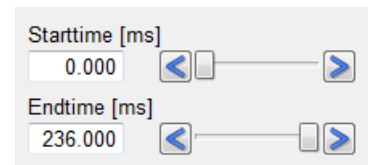
condition 2 are displayed in blue. Time-ranges, during which group / condition 1 has larger values than condition 2 are displayed in red. If desired, the mask as well as each of the groups / conditions can be switched off by un-checking the tick-mark in the according selector boxes.

**Display Top/Right** in the Interaction Window determines what will be displayed in the right Detail Window and the Main Window. A selection can be made between **Difference**, i.e. the difference between groups / conditions or the according **T-Values**. It is also possible to display the **Mask** of significant time-periods in the right Detail Window analogue to the left Detail Window.

Please see chapter 14.4.2 for more details on display settings.

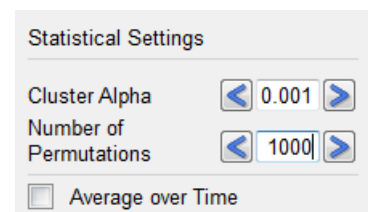
If desired, the **Starttime** and **Endtime** can be adjusted.

In the current example the whole time-range from 0 to 236 ms will be used.



Please note that it is not possible to specify a **Neighbor Distance** for image data. The reason is that the neighborhood structure is given for a volume image consisting of adjacent voxels. I.e. the **neighborhood information is automatically retrieved by BESA Statistics!**

If desired, the **Cluster Alpha** value can be adjusted. The default value is 0.05. In the current example a p-value of 0.001 will be used..



If desired, the **Number of Permutations** can be adjusted. The default setting is 1000. This will be used in the current example.

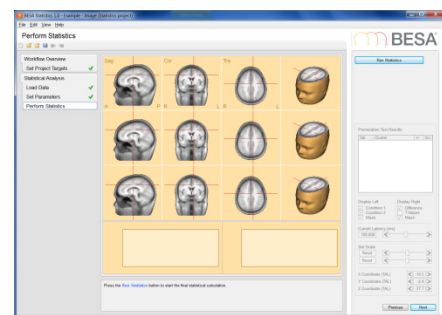
In the current examples, **Average over Time** will not be used.

Please see chapter 14.4.2 for more details on statistical settings.

Press **Next** or hit the space bar to proceed to the next workstep.

## 18.4. Perform Statistics

Hit **Run Statistics**, press the space bar or press **Next** to start the permutation statistics.

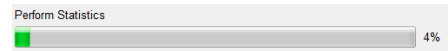
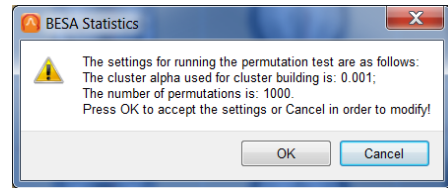


A window will appear showing the summary of the Statistical Settings as defined in step 18.3.

Pressing **OK** will start the permutation statistics. **Cancel** will allow moving back to Set Parameters by pressing **Previous** in the Interaction Window or by selecting **Set Parameters** in the Workflow Window.

Press **OK** to start the permutation statistics.

The Information Window will display the progress of the permutation statistics. Please note that it can take several minutes to complete the calculations depending on the number of subjects, the number of channels and sampling points.



The permutation test results in the current example are 6 significant clusters (see 8.2) I. By default, BESA Statistics automatically selects the most significant cluster and visualizes the data of the voxel with the largest absolute t-value in the Detail Windows.

You may browse through the clusters to see their location and time-course.

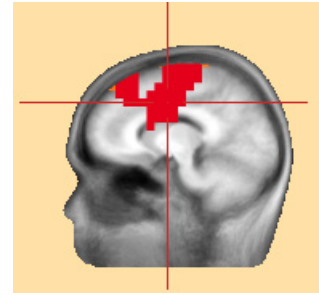
The most significant cluster is negative, i.e. condition 1 has smaller values than condition 2 in medio-frontal brain area.

**Permutation Test Results**

Val	Cluster	+/-	Vis
★★★	001 [p=0.00000]	+	✓
★	002 [p=0.01000]	+	✓
★	003 [p=0.01000]	+	✓
★	004 [p=0.01000]	+	✓
★	005 [p=0.02000]	+	✓
+	006 [p=0.03000]	+	✓
	007 [p=0.06000]	+	
	008 [p=0.06000]	+	
	009 [p=0.09000]	+	
	010 [p=0.20000]	-	

All voxels belonging to a cluster are colored red (positive cluster) or blue (negative cluster).

See more details on cluster visualization in chapter 14.5.



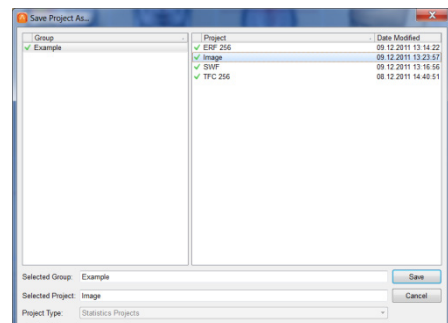
Information on all significant clusters is summarized in the Information Window. The following information is given:

- cluster number
- cluster p-value
- mean of group / condition 1
- mean of group / condition 2.

Clusters	p-values	Mean 1	Mean 2
Cluster 1	0	0.16177	0.0662406
Cluster 2	0.01	0.108403	0.0552723

Click on **Finish** to save and close the project.

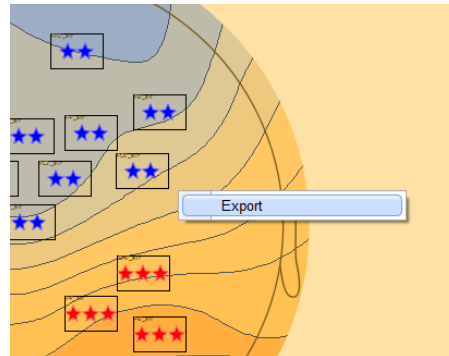
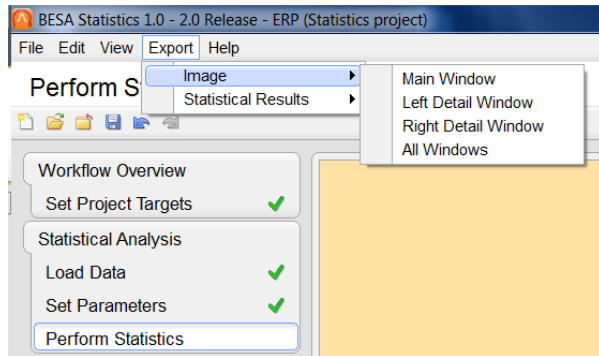
Please enter a **Group** and **Project** name. The project can be re-loaded at any time (see 9). All previous worksteps are saved and can be re-visited without repeating calculations.



## 19. Exporting Images and Results

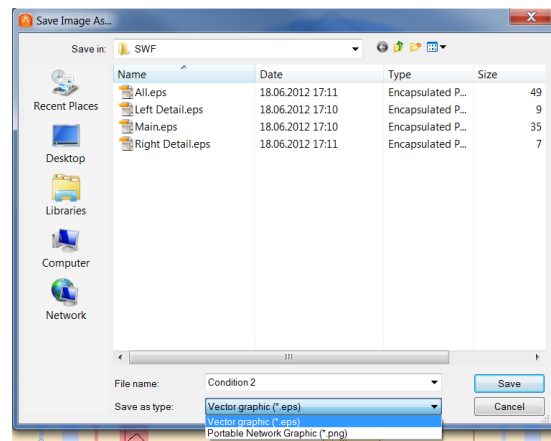
### 19.1. Exporting Images

After running preliminary statistics or after the Perform Statistics workstep is finalized it is possible to export resulting images in the main window and the detail windows. This can be achieved via the menu bar (see 12.1.4) or via right-clicking in the according window.



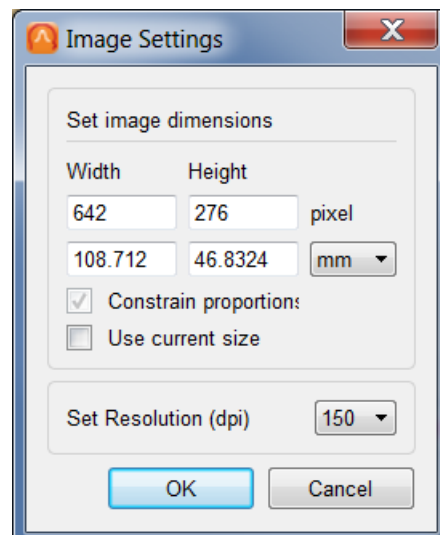
Images can be saved as **portable network graphics** (\*.png) or **vector graphics** (\*.eps).

The selection can be made in the saving dialogue under **Save as type**:



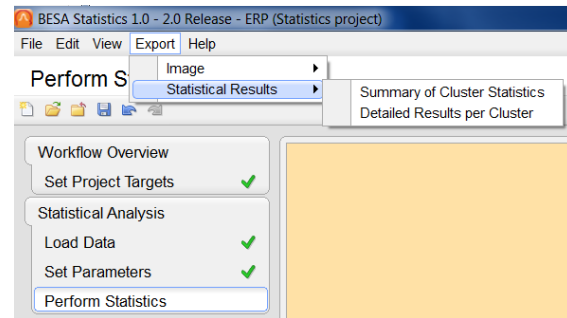
When saving \*.png files, the dimension and resolution of the resulting image can be defined. By default, the current size of the image on the screen is used. Width and height can be altered with or without constraining proportions using mm or inch as units. The resolution can be set to 150, 300 or 600 dots per inch.

When saving \*.eps files the image size cannot be changed as vector graphics are by definition fully resizable.



## 19.3. Exporting Statistical Results

After the Perform Statistics workstep is finalized it is possible to export statistical results via the menu bar (see 12.1.4). A choice can be made between “Summary of Cluster Statistics” and “Detailed Results per Cluster”. The resulting files are comma-separated.



**Summary of Cluster Statistics** will output the cluster value, p-value, cluster boundaries and means for condition/group 1 and 2 for each cluster found. For ERP/ ERF and TFC data, labels of the channels that are associated with a cluster are also exported.

	A	B	C	D	E	F	G	H	I
1	Cluster ID	p-value	Cluster value	Mean for High	Mean for Low	Start Time	End Time	Start Frequency	Frequency
2	Cluster 1	0	1968.64	142.438	0.308131	144	484	0	0
3	Cluster 2	0.001	-1505.43	-143.998	-0.351573	252	548	0	0
4	Cluster 3	0.003	-537.501	-138.388	0.0501521	152	240	0	0
5	Cluster 4	0.009	-394.209	-245.404	-109.723	72	132	0	0
6	Cluster 5	0.056	214.41	209.692	-0.208071	68	128	0	0
7	Cluster 6	0.057	-212.52	-0.93748	-0.110508	572	644	0	0

...

**Detailed Results per Cluster** will output mean values per person and group/condition for each cluster.

File Name	Group/Condition	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	...
S1_av-exp	High	171.953	-151.161	-194.226	-263.472	0.801743	-0.507554	...
S2_av-exp	High	169.847	-181.393	-136.974	-505.065	341.797	-157.004	...
S3_av-exp	High	145.465	-160.939	-0.763417	-308.214	271.868	-0.869147	...
S4_av-exp	High	208.697	-200.994	-282.052	-168.923	220.373	-0.962667	...
S5_av-exp	High	0.97476	-116.565	-0.769849	-0.856455	0.872301	-18.556	...
S6_av-exp	High	191.059	-198.049	-141.889	-389.266	424.777	-0.356282	...
S7_av-exp	High	110.585	-132.591	-105.209	-131.805	-0.285907	-0.332387	...
S8_av-exp	High	116.152	-108.109	-0.81392	-0.738287	0.0227702	-0.72513	...
S9_av-exp	High	0.445815	-0.88784	0.176864	-233.962	240.692	-0.845003	...
S10_av-exp	High	168.562	-101.396	-306.497	-293.862	460.878	-135.099	...
S1_av-exp	Low	0.643345	-0.626427	-0.36212	-128.735	-0.628347	-0.282522	...
S2_av-exp	Low	0.59677	-0.681179	-0.1748	-271.552	0.938874	-0.371693	...
S3_av-exp	Low	0.0202673	-0.110512	0.431863	-106.496	-0.256526	-0.231328	...
S4_av-exp	Low	0.721863	-0.556209	-0.448149	-0.711987	-0.436034	0.275218	...
S5_av-exp	Low	0.161173	-0.47262	0.152608	-0.349198	0.217433	-0.421711	...
S6_av-exp	Low	0.469015	-0.533854	0.0798142	-191.912	0.542202	0.0566957	...
S7_av-exp	Low	-0.155377	-0.149824	0.434543	-0.605937	-0.473177	0.934194	...
S8_av-exp	Low	0.408926	-0.377373	0.168674	-0.268427	-115.001	-0.418365	...
S9_av-exp	Low	0.0253412	-0.16751	0.595101	-0.932934	-0.485215	0.112018	...
S10_av-exp	Low	0.240665	0.159776	-0.376014	-111.691	-0.349912	-0.757587	...

## 20. Appendix

### 20.1. How to deal with bad channels when analyzing ERP / ERF data

By default, BESA Statistics only utilizes information about EEG / MEG channels configurations as available in the elp-file (see 14.3.1 and 21). The elp-file does not contain information on channel status, e.g. channels that were excluded from analysis in BESA Research by setting them as bad. Thus, all channels that were previously defined as bad will still be used by BESA Statistics. This might not be desirable, as the channels might contain flawed data.

However, it can be a problem for cross-subject statistics if bad channels are defined and shall be excluded. If different bad channels are defined for different subjects, the number of channels does not match across subjects. This is a requirement for cross-subject statistics as it is implemented in BESA Statistics, however. There are two ways to deal with this problem:

### 20.1.1. Interpolating bad channels in BESA Research

The easiest solution might be to interpolate all bad channels in BESA Research by right-clicking on the channel label and choosing “Interpolate this channel” rather than “Define channel as bad”.

Alternatively, you can press “Edit / Bad Channels” and double-click on all channel labels in the right panel. This will also lead to bad channels being interpolated. After interpolation you should export (“File / Export”) the data with the setting “Current Montage”. This will lead to BESA Research outputting the interpolated EEG / MEG channel traces rather than the flawed data of the bad channels.

### 20.1.2. Creating a channel montage only containing good channels in BESA Research

If you want to omit bad channels from statistical analysis, you should create a new channel montage in BESA Research. With a concerned dataset open, press “Edit / Montage” to open the montage editor. In the middle pane you can now delete all channels you want to omit from statistical analysis by right-clicking and selecting “Delete montage channel ...”. Save the newly created montage by pressing “File / Save Montage as”. Please specify a name of your choice. This user-montage can now be applied to the datasets of all subjects that should enter statistical analysis by pressing the USR button and selecting the according montage for each dataset.

The data can now be exported for statistical analysis (“File / Export”) with the settings “ASCII vectorized” and “Current Montage”. This will make sure that all subjects are associated with the same number of channels.

What you will need to do additionally is to export a new elp-file containing only information about the channels in the montage. To do so, make sure that the montage you want to use is applied on the data. Next, press “**File / Head Surface Points and Sensors / Save Electrode File for Current Montage**”. This will make sure that the number of channels and the labels of the used channels are identical in the exported data and the elp-file.

## 20.2. How to deal with re-montaged or re-referenced data

In case you have already created a channel montage only containing channels of interest or if you are dealing with re-referenced data, you should follow the same procedure as outlined in chapter 20.1.2., second and third paragraph.

## 21. File Formats

In case BESA Statistics is used for data created in other software, files need to be prepared to meet file format expectations.

In the following we describe the requirements which data created using other software should meet to be compatible with the BESA Statistics data formats described in the table of section 14.3.1. All BESA Statistics data formats are in ASCII format to facilitate human readability. All floating point numbers are represented in scientific notation with up to eight significant digits.

### 21.1. The BESA Statistics Time-Frequency File Format (\*.tfc)

The header line contains the following data descriptors (13 descriptors displayed in **bold**, the values shown are only examples and comments are in *italic*):

1. **VersionNumber**=\_\_v\_5.1: *Version number of the current software.*
2. **DataType**=COHERENCE\_SQUARED: *Data type contained of the file. Possibilities are:*
  - COHERENCE\_SQUARED: *coherence values squared.*
  - ERDERS\_AMP: *ERD(event-related desynchronization) and ERS(event-related synchronization) amplitudes.*
  - ERDERS\_POWER: *power.*
  - ERDERS\_AMP\_P\_VALUE *(not allowed for BESA Statistics)*
  - ITPL: *Inter-trial phase locking is a measure for the phase consistency of the oscillatory response of a single surface or source channel across multiple trials.*
  - PHASE\_COHERENCE: *phase coherence.*
  - ERDERS\_AMP\_P\_VALUE *(not allowed for BESA Statistics)*
  - TIME\_FREQUENCY\_AMP: *time frequency amplitude.*
  - TIME\_FREQUENCY\_POWER: *power.*
3. **ConditionName**=s: *Condition name. Usually indicated by experiment. E.g. "high-" or " low intensity".*
4. **NumberTrials**=250: *Number of trials.*
5. **NumberTimeSamples**=25: *Number of time samples.*
6. **TimeStartInMS**=-100.0: *Start time in [ms].*
7. **IntervallInMS**=25.0: *Interval length in [ms].*
8. **NumberFrequencies**=24: *Number of frequency bins.*
9. **FreqStartInHz**=4.0: *Starting frequency in [Hz].*
10. **FreqIntervallInHz**=2.0: *Frequency interval in [Hz].*
11. **NumberChannels**=127: *Number of channels in the data set.*

12. **StatisticsCorrection=Off:** *Statistics correction flag.*

13. **EvokedSignalSubtraction=Off:** *Flag to signal evoked signal subtraction (On if evoked signal is subtracted, Off otherwise).*

The second row of the header contains the labels of the channels. Their labeling can be chosen freely provided only letters and number are used and the amount of characters per entry does not exceed eight (e.g. E1 E2 ... for electrodes).

The remaining lines contain **NumberChannels** blocks starting from the first channel. Each block is separated from the next one by an empty line. Each block contains **NumberFrequencies**-rows and **NumberTimeSamples**-columns. The values for each time-frequency entry in the blocks are floating point numbers and should be separated by a tab.



## 21.2. The BESA Statistics Channel Definition File Format (\*.elp)

Each line of the channel definition file contains one label, an identifier and 2D coordinates. The format is: **Identifier Label Theta-coordinate Phi-coordinate**.

Identifiers can be:

- **EEG** -- scalp electrode (use also instead of SCP).
- **POL** -- polygraphic channel (use also instead of PGR).
- **ICR** -- intracranial electrode.
- **MEG** -- MEG sensor.
- **REF** -- reference electrode. This can only occur once.

Labels should have at most 8 characters and be constituted only by letters and numbers, but can otherwise be chosen freely. Note though that the corresponding \*.avr files (see 21.6) have to use the same convention for the label naming.

Coordinates shall be floating point numbers in [deg] in the unit sphere coordinate system. This coordinate system is defined by reference points on the head known as fiducials. The reference points are normally the nasion (NAS), the left preauricular point (LPA), and the right preauricular point (RPA). The x axis is defined by the line joining LPA and RPA, positive towards RPA. The y axis is defined by the line through NAS that is perpendicular to the x axis (positive towards NAS). The z axis is perpendicular to the x and y axes, and goes up out of the upper part of the head (e.g. Cz). The Theta-coordinate (azimuth) is zero at the z axis, 90 deg at the x axis and -90 deg at the negative x axis. The Phi-coordinate instead goes from [-90 deg, 90 deg] from the negative y axis to the positive y axis for positive theta (i.e. for the right hand side of the scalp), while it goes from [90 deg, -90 deg] from the negative y axis to the positive y axis for negative theta (i.e. for the left hand side of the scalp).

### 21.3. The BESA Statistics Solution File Format (\*.bsa)

The file contains the position and orientation of dipoles/sources.

The first line of the file shall contain a dummy identifier **BSA\_1.04.19990715**.

The second line of the file shall contain the labels: **Type**, **x-loc**, **y-loc**, **z-loc** (the position of the dipole/source in unit sphere Cartesian coordinates), **x-ori**, **y-ori**, **z-ori** (the unit vector orientation of the dipole/source).

This coordinate system is defined by reference points on the head known as fiducials. The reference points are normally the nasion (NAS), the left preauricular point (LPA), and the right preauricular point (RPA). The x axis is defined by the line joining LPA and RPA, positive towards RPA. The y axis is defined by the line through NAS that is perpendicular to the x axis (positive towards NAS). The z axis is perpendicular to the x and y axes, and goes up out of the upper part of the head (e.g. Cz).

Type can assume the values:

1. **SngDip** - single dipole.
2. **RegSrc** - regional source.

## 21.4. The BESA Statistics Image File Format (\*.dat)

Source analysis files are used to store a number of possible scenarios:

- **Image ASCII Files:** Image amplitudes of all grid points in the currently displayed image in the current image resolution.
- **Image ASCII Files - all latencies:** Image amplitudes of all grid points in the current image resolution for all time points.

The header shall look like (required labels are in **bold**, comments are in *italic* and all other text serves as sample input):

**BESA\_SA\_IMAGE:2.0**

**Data file:** C:\ExampleDirectory\exampleFile.foc: *Meta information.*

**Condition:** s Low Filter: 0.5 Hz: *Condition name, usually specified by the experiment.*

**Method:** Standard LORETA: *Used method. See below.*

**Regularization:** First: SVD 0.0050Iterations: SVD 0.0050;: *Meta information.*

**nAm/cm<sup>3</sup>**

**Grid dimensions ([min] [max] [nr of locations]):**

**X:** -73.500000 73.500000 22: *Min, max and number of points along the X axis.*

**Y:** -107.930000 74.070000 27: *Min, max and number of points along the Y axis.*

**Z:** -60.340000 79.660004 21: *Min, max and number of points along the Z axis.*

=====

**Method** can assume the following values:

- MSBF
- CLARA
- Standard LAURA
- Standard LORETA
- Standard sLORETA
- Standard swLORETA
- Standard SSLOFO: 3 iterations, clip 10, smooth 1.0;

The data section following the header is composed of matrixes of **nr of locations** - of **X** columns and **Y** rows with values for each voxel at this slide indexed by **Z**. There are **nr of locations** (specified in the header for **Z**) slides and the index starts at zero. Each slide is separated by a blank line.

The data section for **Image ASCII Files** will look like e.g.:

```
.
.

Z: 12

0.0000000000 0.0000000000 0.0000000000 0.0000000000 ... nr of locations of X entries.
0.0000000000 0.0000000000 0.0000000000 0.0000000000
0.0000000000 0.0000000000 0.0000000000 0.0000000000
0.0000000000 0.0000000000 0.0000000000 0.0000000000
0.0000000000 0.0000000000 0.0000000000 0.0000000000
0.0000000000 0.0000000000 0.0000000000 0.0000000000
0.0000000000 0.0000000000 0.0000000000 1.1316120625
0.0000000000 0.0000000000 0.0000000000 1.6725080013
0.0000000000 0.0000000000 1.0726528168 2.2005338669
0.0000000000 0.0000000000 1.5812959671 2.8961703777
0.0000000000 0.0000000000 2.1061606407 3.6263871193
0.0000000000 0.0000000000 2.6111714840 4.3519711494
0.0000000000 0.0000000000 2.8889267445 4.7082519531
0.0000000000 0.0000000000 2.8630757332 4.6019945145
0.0000000000 0.0000000000 2.5799186230 4.1517233849
0.0000000000 0.0000000000 2.1543741226 3.4361450672
.
.

... nr of locations of Y entries.
.
```

For each time sample the corresponding data block starts with the label **Sample** and the number of the current sample e.g. 1, and after a comma separator follows the latency in milliseconds followed by the unit label "ms". Furthermore the amount of equal signs to limit each latency sample is 94.

The data section for **Image ASCII Files - all latencies** - all latencies will look like e.g.:

```
.
.
.
```

Sample 1, 0.00 ms

Z: 0

0.0000000000 0.0000000000 0.0000000000 0.0000000000 ... **nr of locations of X entries.**

.

.

... **nr of locations of Y entries.**

Z: 1

.

.

.

=====

Sample 2, 4.00 ms

Z: 0

.

.

.

## 21.5. The BESA Statistics Source Waveforms File Format (\*.swf)

The header line contains the following data descriptors (8 descriptors displayed in **bold**, separated by blank spaces, the values shown are only examples. Comments are in *italic*.):

1. **Npts=** 200: *number of sampled points in each channel.*
2. **TSB=** -500: *time sweep begin [ms]. Time of first data point relative to zero of epoch.*
3. **DI=** 5: *digitization or sampling interval [ms].*
4. **SB=** 1: *default scaling bins/nAm in file.*
5. **SC=** 200: *default scaling calibration.*
6. **CondFile=** "OrigFile.fsg": *Name of the original bin file.*
7. **CondName=** "S1: 100 avs": *Condition name, usually specified by the experiment.*
8. **Filter=** "Filters off": *status of the filters.*

Each remaining line begins with the name of the source followed by floating point values for all **Npts** time points.

In the case of regional sources which are previously oriented after the export we get three rows for each source (one for each orientation).

## 21.6. The BESA Statistics ERP / ERF ASCII Vectorized File Format (\*.avr)

The first of two header lines contains the following data descriptors (7 descriptors, the values shown are only examples):

1. **Npts=** 200: *number of sampled points in each channel.*
2. **TSB=** -500: *time sweep begin [ms]. Time of first data point relative to zero of epoch.*
3. **DI=** 5: *digitization or sampling interval [ms].*
4. **SB=** 1: *default scaling bins/nAm in file.*
5. **SC=** 200: *default scaling calibration.*
6. **Nchan=** 27: *number of channels.*
7. **SegmentName=** 60dB : *an optional label describing the data.*

The second line of the header contains the labels for each channel separated by a blank space. They can be chosen freely, however they have to correspond to whatever convention was used in the corresponding (see 21.2).

Each of the subsequent **Nchan** lines of the file contains floating point values for all **Npts** time points.

## 22. References

- Abdi, H. (2007). Bonferroni and Sidak corrections for multiple comparisons. Encyclopedia of Measurement and Statistics. N. J. Salkind. Thousand Oaks, CA, Sage
- Bullmore, E. T., J. Suckling, et al. (1999). "Global, voxel, and cluster tests, by theory and permutation, for a difference between two groups of structural MR images of the brain." IEEE Trans Med Imaging **18**(1): 32-42.
- Ernst, M. D. ( 2004). "Permutation methods: a basis for exact inference." Stat Sci **19**(4): 676–685.
- Hays, W. L. (1988). Statistics. New York, CBS College Publishing.
- Maris, E. and R. Oostenveld (2007). "Nonparametric statistical testing of EEG- and MEG-data." J Neurosci Methods **164**(1): 177-190.

BESA GmbH  
Freihamer Str. 18  
82166 Gräfelfing – Germany

Phone + 49.89.89 80 99 66  
Email [info@besa.de](mailto:info@besa.de)  
Web [www.besa.de](http://www.besa.de)



The CE marking certifies that this product fulfills the basic requirements of the Medical Devices Directive MDD 93/42/EEC. The number represents the identification number of the Notified Body which carried out testing and certification.

© Copyright 2015

