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Handout for the tutorial "Enhanced Eye tracking Analysis by Adding Additional Channels and AI to the Picture" at ETRA 2023

Eye tracking, skin conductance and EEG in practical use - a guide for users

BIOSIGMA
Biosignal Measurement and Analysis

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1 Introduction

Eye tracking technology has become an important tool in research in recent years. The ability to track the eye movements of test subjects opens up new possibilities in many areas, from market research to medical diagnostics.

Eye tracking is a method based on objective measurements that provides a variety of data that can contribute to the interpretation of visual perceptual processes. By combining eye tracking with psychological data, the emotional state of the test person can be synchronized and evaluated with the results of the eye tracker. This facilitates, for example, the verification of marketing statements using objective parameters ("neuromarketing"). For market research purposes, the combination can be used to find out whether and how a brand has an emotional impact. Further information on the topic of emotions in marketing can be found in (Stürmer & Schmidt, 2014). In the area of user experience (UX), the subject's reactions can be more precisely assigned to situations or events. In the case of user experience, negative emotions such as confusion and annoyance are in the foreground. That these examples are only the beginning, however, is shown by an application in which the combined measurement of eye tracking and GSR is used to improve the suspense arcs in television series.

This handout explains how to use BiSigma hardware and software solutions from recording to evaluation using practical procedures. In addition, explanations of the background should enable the user not only to copy the described procedure, but also to modify and expand it with regard to his or her own questions.

2 Recording

Various software products such as PsychoPy, Tobii Pro Lab or SuperLab can be used to record biosignals. Our own recording software within the BiSigma Software Suite is currently under development. Recording can be done with eye tracking glasses or remote eye trackers. For recording, eye tracking can be combined with one or more other biosignals.

With the help of skin conductivity, emotional reactions to stimuli can be detected (Galvanic Skin Response, GSR). The type (direction) of the emotion cannot be determined with this physiological value, only the strength of the reaction can be depicted. However, the direction of the emotion can usually be determined from the context or by subsequently questioning the test person. In contrast to a subjective assessment of the strength of the stimulus, the evaluation of the GSR curve offers an objective value. Analogously, other electrophysiological data such as an electrocardiogram (ECG) can be recorded. The ECG can be used to determine parameters such as the heart rate, which also allow objective conclusions to be drawn about emotional and cognitive states.

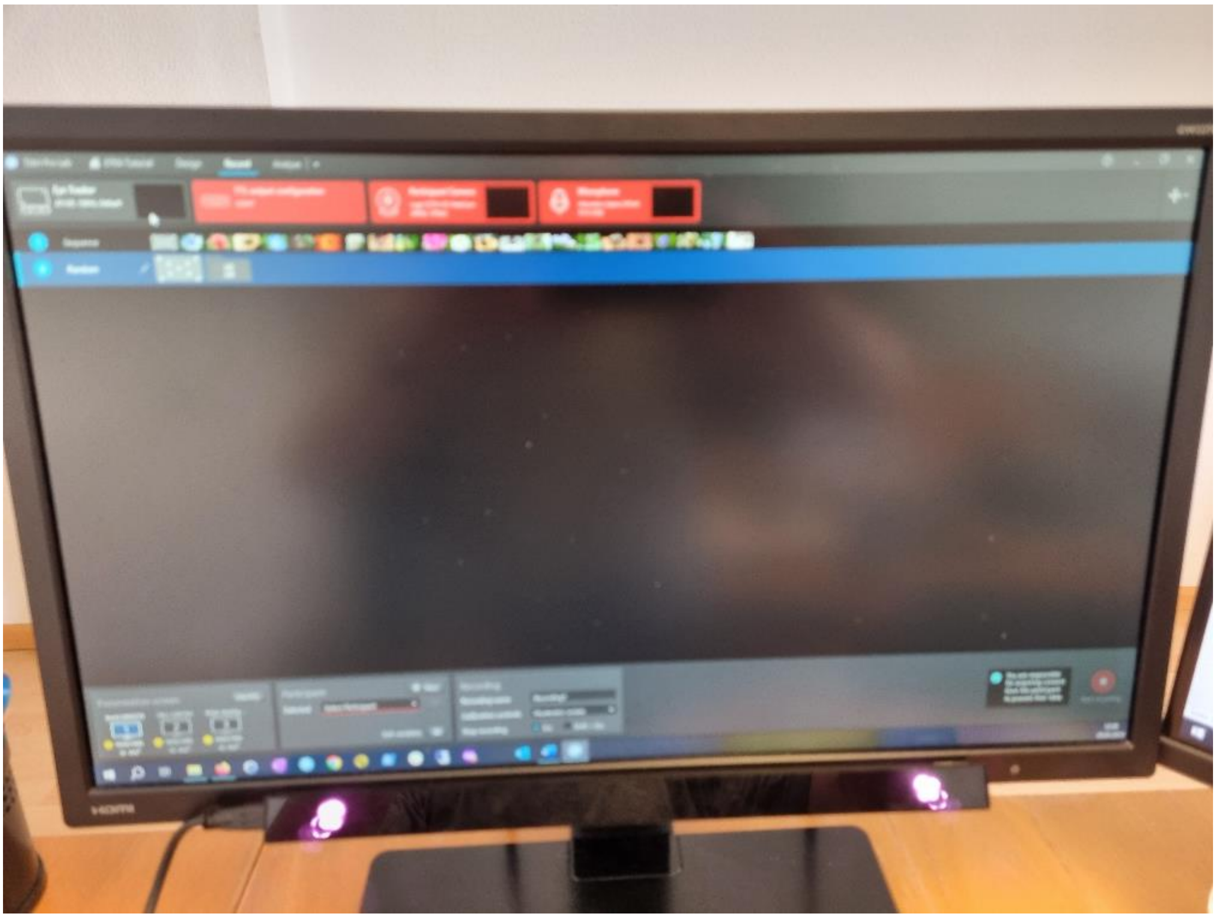
Research into the electrical activity of the brain began as early as 1924. The phenomenon of the so-called alpha block, a reaction of brain waves to increased mental activity, is already known from this time. In addition to alpha waves, electrical brain activity is also divided into beta, gamma, delta and theta waves. Depending on where they were measured on the surface of the head, conclusions about different mental activities can be drawn from the activities in the respective frequency bands. The examination of EEG signals (electroencephalography) is very complex and requires a certain amount of background knowledge in addition to good, high-quality equipment.

2.1 Hardware eye tracking

In the tutorial, the remote eye trackers Tobii Pro X3-120 and nano or the eye tracking glasses Tobii Pro Glasses 3 are used as examples. Other eye trackers that can be used are the Hiru from the company Irisbond and the eye tracking glasses from Viewpointsystem and Pupil Labs.

In stationary applications, the eye tracker is typically attached to a monitor ("remote" in relation to the subject). The eye tracker is connected to the test computer by cable via USB. The eye tracker must be adjusted and calibrated to the test person.

For mobile applications, eye tracking glasses are used. The eye tracking glasses store the recorded data independently in the mobile unit. These can be read out later for further analysis.



Monitor with Remote Eyetracker

2.2 Software eye tracking

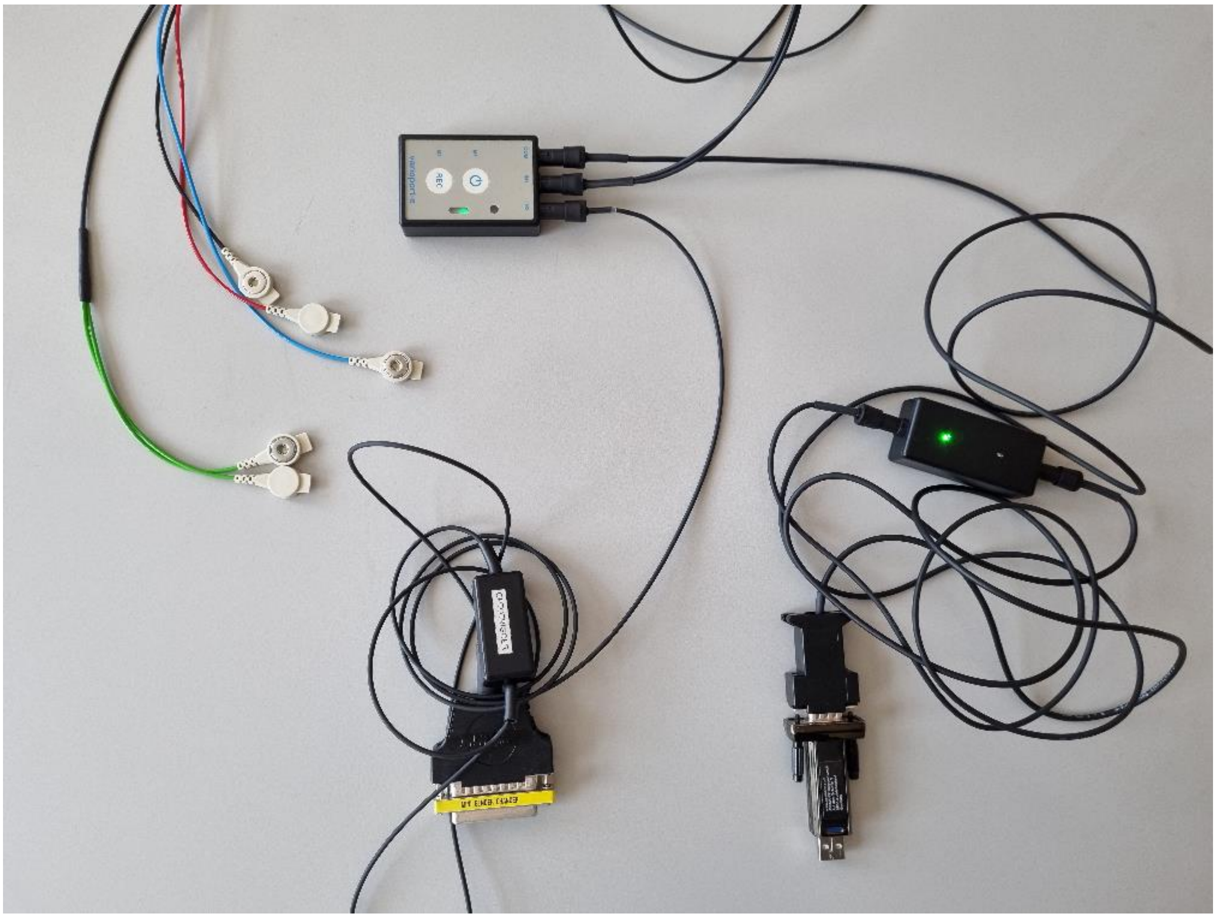
Remote eye trackers require software on the connected computer for presentation and for recording the eye tracking data. In the tutorial, the software products Tobii Pro Lab and Superlab X6 are used as alternatives. Both products have individual strengths but also limitations, which will be explained in more detail in the tutorial.

Eye tracking glasses do not require any further software for recording, as this is already integrated into the recording unit of the glasses. The stimulation of the test persons is done by the environment in which the experiment is conducted and usually does not require any further software either.

2.3 Hardware GSR/ECG

The GSR data is recorded with the help of electrodes, just like an ECG. To measure GSR, the electrodes are stuck on the palm of the subject's hand, for an ECG they are placed on the chest. In the tutorial, the varioport is used as an amplifier. Depending on the device type, the recording of up to 16 electrical channels is supported. For stationary applications, the amplifier is connected to the recording PC via USB. For mobile applications, a portable amplifier is used, which first stores the data on an SD card that can be read out later for analysis.

In order to obtain a meaningful measurement, care should be taken to ensure good contact between the electrode and the test person when recording the responses. Likewise, care should be taken to ensure that the subject's hand is in as little movement as possible for the duration of the recording. In motor tasks, the electrodes should therefore be attached to the less active hand if possible, i.e. right-handed people on the left and vice versa.



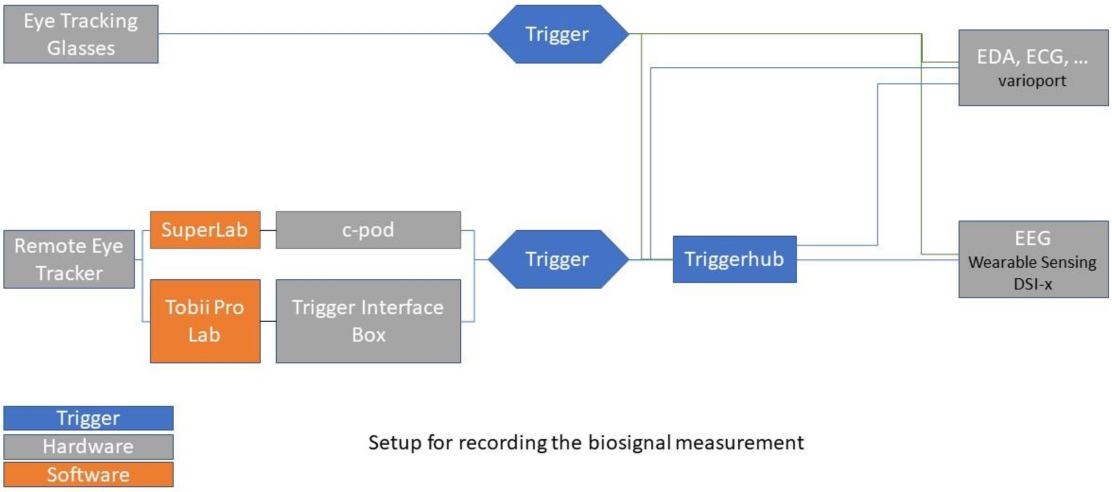
varioport-e with GSR and ECG

2.4 Software GSR/ECG

The Biometric Software Suite is used to record the electrophysiological signals; its functions will be integrated into the BiSigma Software Suite in the future

2.5 Synchronisation between the signals

For the later simultaneous analysis of eye tracking and electrophysiological signals, it is necessary to establish a temporal reference between the different recording systems during the recording. For this purpose, trigger impulses are continuously sent from the eye tracking system to the amplifier, where they are stored in the signal in the form of markers or tags and enable a comparison of the time axis for the data sets during later analysis, even if the sampling rate of the signals differs. The following diagram illustrates this scenario.



Setup for recording the biosignal measurement

If only one other system is used in addition to the eye tracker to record physiological signals, the trigger impulses are typically transmitted via a parallel port adapter. The Tobii Glasses 3 have a trigger output via jack plug.

Trigger interfaces with parallel port adapter

If further amplifier systems are used, such as an EEG system, the trigger signal must be split and fed separately into all amplifiers used. This is done via a trigger hub, which has different input channels for hardware triggers and can in turn pass on the received triggers to the connected hardware via different channels.

Setup Trigger Interface Box, trigger hub, varioport-e and EEG DSI-24

2.6 Hardware and software EEG

There are numerous systems for recording EEG data. BiSigma offers the EEG headsets DSI-7 and DSI-24 in its portfolio, which work with dry electrodes and thus enable uncomplicated preparation. The headsets send the data to a recording computer via Bluetooth, so that mobile use in combination with eye tracking glasses is also possible.

DSI-24 with accessories

2.7 The experiment

For the tutorial, a simple experiment was prepared in which the test persons are shown pictures of spiders and flowers in random order for 20 seconds each. The experiment was created in Tobii Pro Lab as well as in Superlab, so that a good comparison of the systems is possible.

After all components of the experimental setup are connected to each other and to the test person, the experimental setup should first be tested and the data quality of the physiological data validated. A good signal for skin conductivity shows a predominantly constant curve between 5 µS and 20µS. A clean ECG shows the typical R-spikes in the pulse spacing.

With EEG systems, an impedance test must be done to ensure that there is sufficiently good conductivity between the head surface and the electrodes. This is done in the recording software of the EEG system. In addition, spontaneous alpha activity can also be generated here by asking the subject to close their eyes briefly.

As the triggers for synchronisation are sent by the eye tracking software, it is necessary to start the recording of the physiological data first to ensure that all synchronisation markers are captured by the amplifier and integrated into the data set.

Therefore, first start the recording of GSR, ECG and EEG and check the signal quality. Only afterwards, please carry out the calibration of the eye tracker, if necessary. Then start the experiment in the eye tracking software. If possible, check on a separate monitor whether the synchronisation markers are recorded and displayed. When finishing the experiment, please proceed in the reverse order: first finish the recording of the eye tracking and then the recording of GSR, ECG and EEG.

2.8 Mobile scenario

In the mobile scenario it is essential that all pulses sent by the Tobii Glasses are recorded by the varioport-e for synchronisation. In this scenario, start the recording directly on the varioport-e. To do this, press the REC button (M2) twice. After the first press, you will hear a signal tone indicating readiness for recording. After the second press, you will see a green flashing signal on varioport-e indicating active recording.

Now start the calibration of the glasses and begin the experiment.

During the experiment, you can mark special times in the data set by pressing the M1 or M2 buttons.

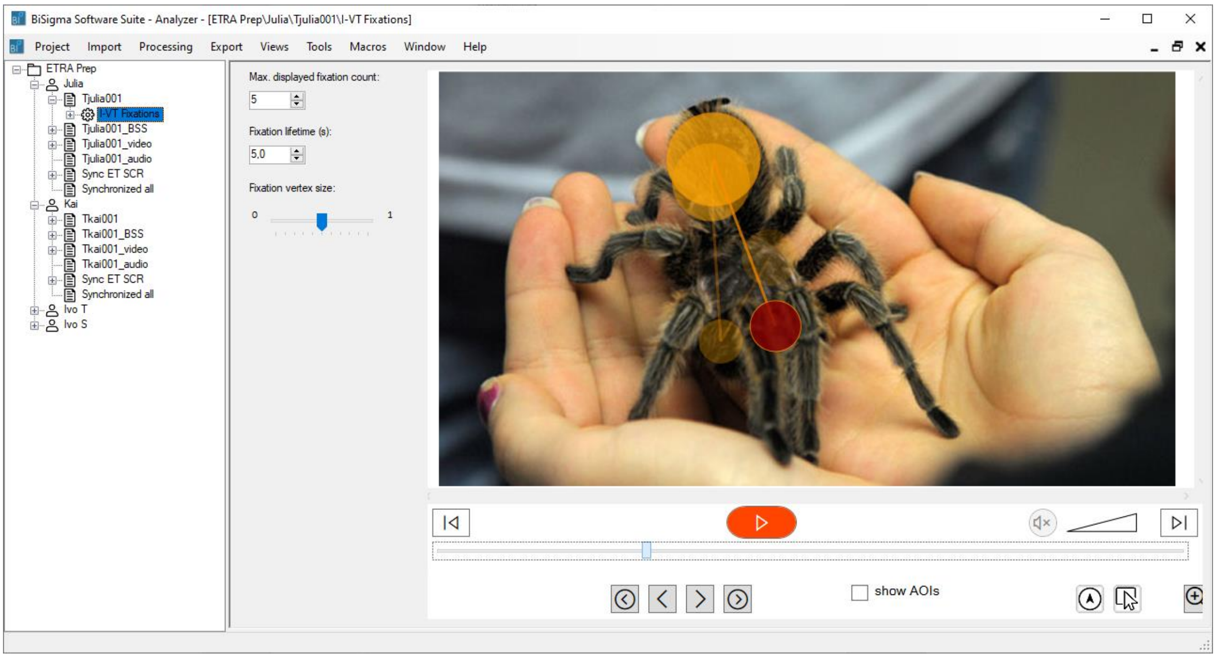
After finishing the eye tracking experiment, stop the recording in varioport-e by pressing the two buttons M1 and M2 simultaneously.

After finishing the recording, you can import the data from the varioport via the USB connection cable. After you have connected the varioport-e to the PC via the USB connection cable, it reports as a normal drive. On it you will find a single file called VPDATA.RAW. Copy this to your hard drive or import the file directly into your workspace using the import function of the Biometric Software Suite. It is automatically copied to a file in the BSS workspace so that you no longer need the varioport-e as a USB drive. During the next exposure, the VPDATA.RAW file on the varioport-e is replaced by the data of the new exposure.

3 Analysis

The BiSigma Software Suite Analyzer is used in the tutorial to analyze the collected data. It is used both for the individual analysis of the different measurement data and for the calculation of combined metrics based on the synchronized data sets.

3.1 The Workspace



Workspace of the BiSigma Analyzer

Analysis projects are organized in workspaces. A workspace is the summary of all data collected during an experiment together with the respective processing steps. These are displayed via a processing tree (left margin). Using the navigation in the processing tree, both the raw data and the results of the individual analysis steps can be displayed and checked at any time. In this way, parameters can be changed and results can be compared with different parameters.

The data is presented in different views depending on the type. Typical default views are often assigned to individual data types, but it is possible to switch these views to inspect different aspects of the data.

The measurement data can be structured according to the test persons (Project > Create Subject). In this way, the measurement data of a subject can be summarized and analyzed together.

3.2 Import

After the optional creation of subject nodes in the workspace, the raw data are loaded into the workspace. For this purpose, various entries for importing the different data types can be found in the Import menu. The following importers are used in the tutorial:

- **Tobii ET Data** for remote eye tracking data from Tobii Pro Lab,
- **SuperLab X6** for remote eye tracking data from Superlab,
- **Biometric Software Suite** for varioport data such as GSR and ECG
- **EDF** for EEG data, especially data from DSI-7 and DSI-24
- **Video** for video data from the webcam or other camera systems
- **Tobii Glasses 3 or Viewpoint system** for mobile eye trackers

The import of generic CSV files, images and audio files is also possible. The analysis tools for audio data are currently still under development.

After the successful import of the raw data, various analysis steps follow, which can be found under the menu item Processing.

3.3 Analysis of eye tracking data

After importing raw eye tracking data, it can be played back in a standard view and inspected visually.

3.3.1 Calculate fixations

The first step in the analysis of eye tracking data is the calculation of fixations. The following functions are available for this purpose:

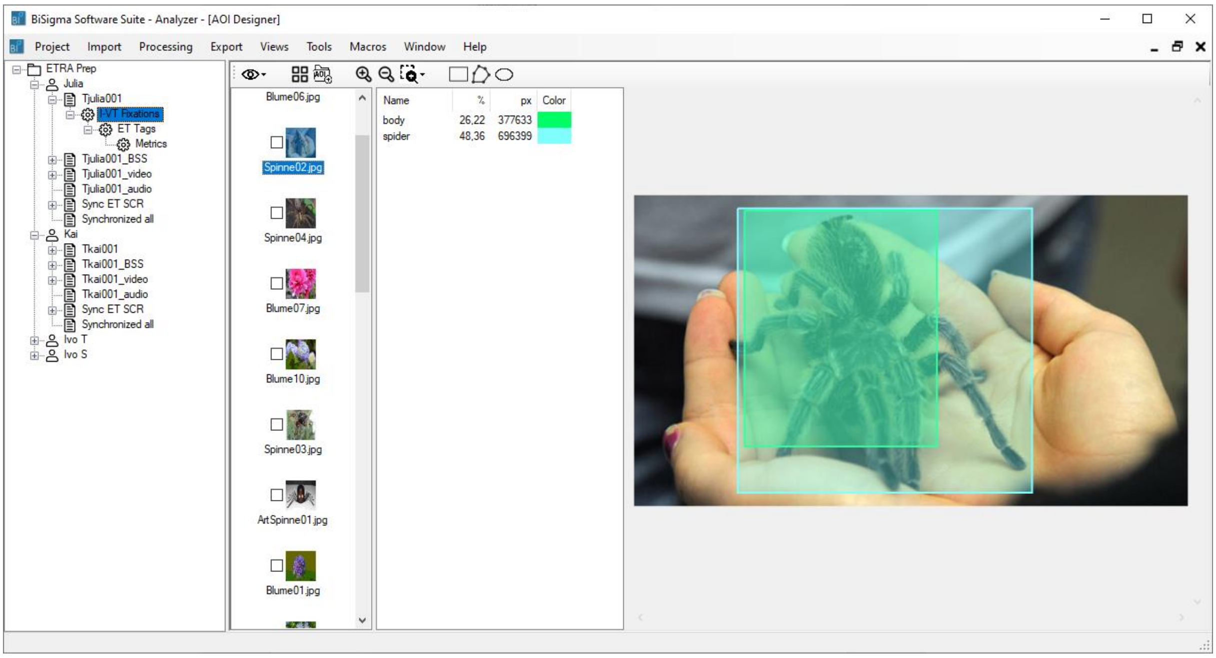
- **Basic Fixation Filter for** calculating fixations according to a pixel-based method,
- **I-VT Fixation Filter for** calculating fixations according to the I-VT principle.

As the calculation of fixations via I-VT requires additional information in the raw data set, this function is not available for all eye tracking data.

After the calculation of fixations, they can be visualized as a gaze path. The representation as a heat map is also possible after this step.

3.3.2 Areas of Interest

Areas of Interest are usually used as a basis for calculating eye tracking metrics. The AOI Designer can be found in the Tools menu to define these areas.

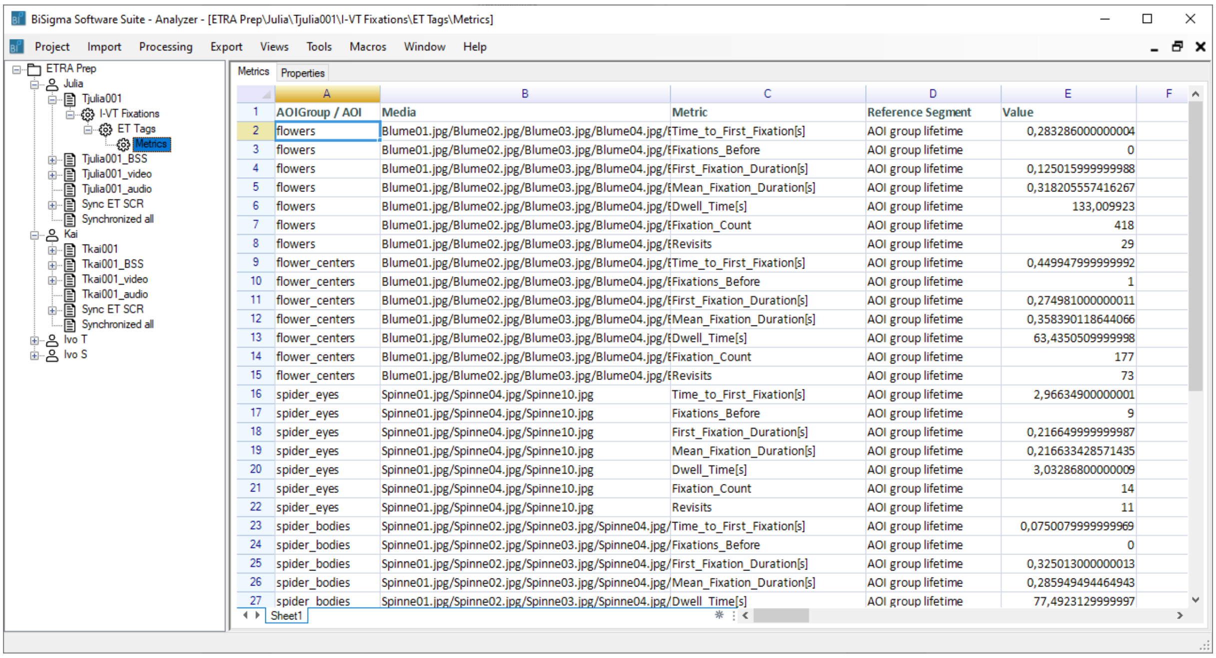


AOI Designer

With the help of the AOI Designer, Areas of Interest of various shapes can be defined. In the case of videos, these can also be defined dynamically over a time range and with variable position. In addition, areas of interest can be grouped together for later evaluation.

3.3.3 Eyetracking metrics

After defining Areas of Interest, the calculation of eye tracking metrics is possible. Various metrics are available under Processing > Eye Tracking Metrics. The result is displayed in tabular form and can be exported for further statistical analysis.



	A	B	C	D	E	F
1	AOIGroup / AOI	Media	Metric	Reference Segment	Value	
2	flowers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Time_to_First_Fixation[s]	AOI group lifetime	0,283286000000004	
3	flowers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Fixations_Before	AOI group lifetime	0	
4	flowers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	First_Fixation_Duration[s]	AOI group lifetime	0,125015999999988	
5	flowers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Mean_Fixation_Duration[s]	AOI group lifetime	0,318205557416267	
6	flowers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Dwell_Time[s]	AOI group lifetime	133,009923	
7	flowers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Fixation_Count	AOI group lifetime	418	
8	flowers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Revisits	AOI group lifetime	29	
9	flower_centers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Time_to_First_Fixation[s]	AOI group lifetime	0,449947999999992	
10	flower_centers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Fixations_Before	AOI group lifetime	1	
11	flower_centers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	First_Fixation_Duration[s]	AOI group lifetime	0,274981000000011	
12	flower_centers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Mean_Fixation_Duration[s]	AOI group lifetime	0,358390118644066	
13	flower_centers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Dwell_Time[s]	AOI group lifetime	63,4350509999998	
14	flower_centers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Fixation_Count	AOI group lifetime	177	
15	flower_centers	Blume01.jpg/Blume02.jpg/Blume03.jpg/Blume04.jpg/E	Revisits	AOI group lifetime	73	
16	spider_eyes	Spinne01.jpg/Spinne04.jpg/Spinne10.jpg	Time_to_First_Fixation[s]	AOI group lifetime	2,96634900000001	
17	spider_eyes	Spinne01.jpg/Spinne04.jpg/Spinne10.jpg	Fixations_Before	AOI group lifetime	9	
18	spider_eyes	Spinne01.jpg/Spinne04.jpg/Spinne10.jpg	First_Fixation_Duration[s]	AOI group lifetime	0,216649999999987	
19	spider_eyes	Spinne01.jpg/Spinne04.jpg/Spinne10.jpg	Mean_Fixation_Duration[s]	AOI group lifetime	0,216633428571435	
20	spider_eyes	Spinne01.jpg/Spinne04.jpg/Spinne10.jpg	Dwell_Time[s]	AOI group lifetime	3,03286800000009	
21	spider_eyes	Spinne01.jpg/Spinne04.jpg/Spinne10.jpg	Fixation_Count	AOI group lifetime	14	
22	spider_eyes	Spinne01.jpg/Spinne04.jpg/Spinne10.jpg	Revisits	AOI group lifetime	11	
23	spider_bodies	Spinne01.jpg/Spinne02.jpg/Spinne03.jpg/Spinne04.jpg/	Time_to_First_Fixation[s]	AOI group lifetime	0,0750079999999969	
24	spider_bodies	Spinne01.jpg/Spinne02.jpg/Spinne03.jpg/Spinne04.jpg/	Fixations_Before	AOI group lifetime	0	
25	spider_bodies	Spinne01.jpg/Spinne02.jpg/Spinne03.jpg/Spinne04.jpg/	First_Fixation_Duration[s]	AOI group lifetime	0,325013000000013	
26	spider_bodies	Spinne01.jpg/Spinne02.jpg/Spinne03.jpg/Spinne04.jpg/	Mean_Fixation_Duration[s]	AOI group lifetime	0,285949494464943	
27	spider_bodies	Spinne01.jpg/Spinne02.jpg/Spinne03.jpg/Spinne04.jpg/	Dwell_Time[s]	AOI group lifetime	77,4923129999997	

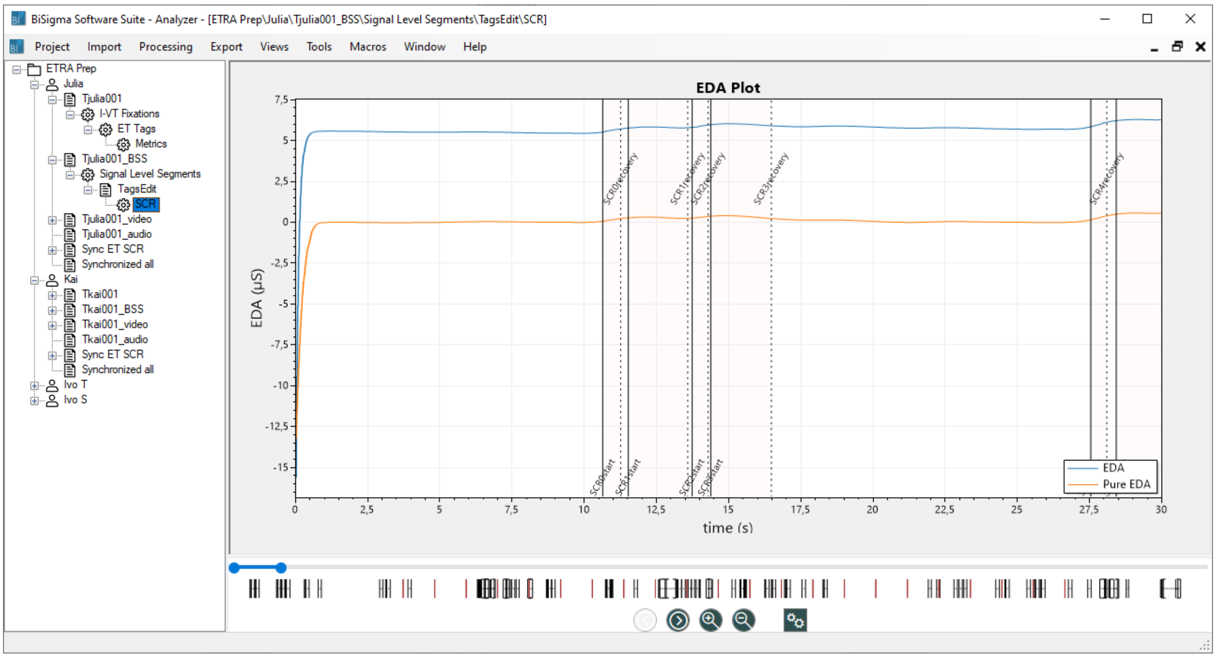
Presentation of metrics in tabular form

3.3.4 Calculation of eye tracking areas

Besides the pure calculation of eye tracking metrics, one of the strengths of the BiSigma software suite is the combined analysis of eye tracking and other data. In order to make events based on the eye tracking data available in other data, a function has been implemented which marks AOI hits on the time axis (Processing > Eye Tracking Segment Markup). This step is done as part of the eye tracking analysis, we will use the results to calculate further metrics after synchronizing the data.

3.4 Analysis of GSR data

Skin conduction responses have characteristic curves in the GSR signal. For analysis, these must be extracted from the raw signal. This is done via the function Processing > EDA Processor SCR. As a result, there are temporal markers in the signal that show the start, maximum and amplitude of the skin conduction response.



Result of the skin conductivity analysis

3.4.1 Analysis of the ECG data

To calculate the heart rate from the ECG data, the function Processing > ECG Processor Heartrate is available.

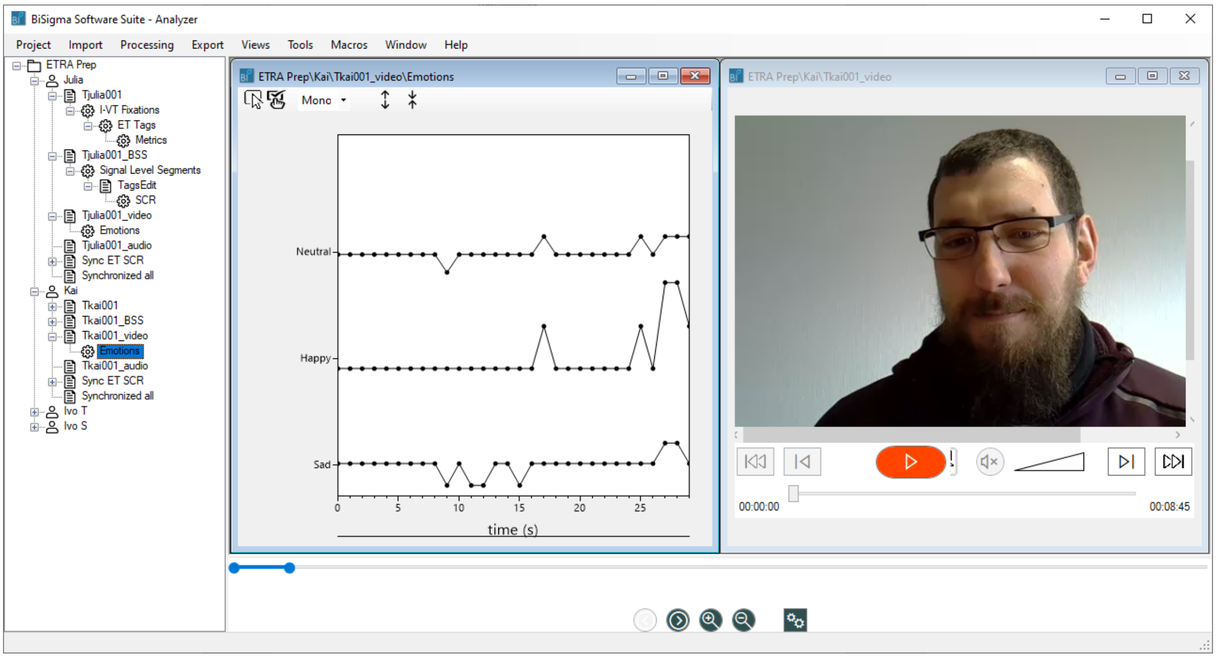
3.4.2 Analysis of the EEG data

The following functions are available for processing and analyzing EEG data:

- **Butterworth IIR filter for** removing noise from the raw signal. This filter can also be applied to GSR signals.
- **RMS/GFP** for calculating the global field power over EEG channels. This represents a measure of the cognitive workload.
- **Sliding FFT** to calculate activity over specific frequency bands.

3.4.3 Video data analysis

In addition to the analysis of electrophysiological signals, the BiSigma Software Suite also offers the possibility to extract emotions from the captured video data. The function is available under Processing > Facial Expression



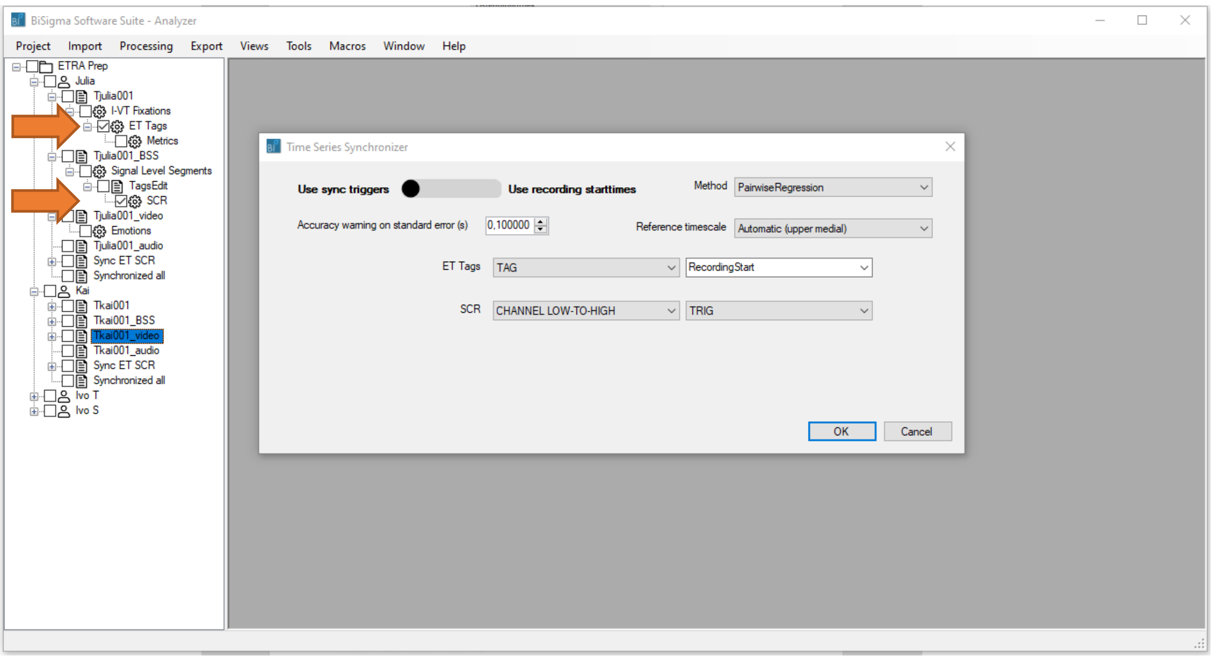
Facial Expressions extracted from the webcam video

3.5 Synchronisation of data and joint evaluation

After a preparatory processing of the individual raw data has taken place, the next step is to merge and jointly analyze the data.

3.5.1 Synchronisation by tags

Data containing synchronization triggers in the form of tags can be automatically combined in the BiSigma Software Suite. To do this, the workspace is first set to Multi Select mode (right mouse button on the tree > Multi Select or Views > Multi Select). Then the data nodes to be synchronized are selected and the Processing > Time Series Synchronizer function is called.



Time Series Synchronizer

3.5.2 Synchronisation by recording time

Data that does not have synchronization triggers, for example video data, can be synchronized via the recording time.

3.5.3 Evaluation

Measured variables to be evaluated are either contained in individual extracted channels (e.g. heart rate, GFP or FFT bands) after the previous steps, or they were stored as values in the properties of tags (e.g. SCR tags). For the extraction of statistical quantities, the following functions are available for this purpose:

- **Evaluate Tag Statistics** calculates metrics from values stored in tags,
- **Evaluate Channel Statistics** calculates metrics from individual channels.

With both functions, restrictive time ranges can be specified based on range tags. For example, an evaluation of GSR or heart rate is possible over the time ranges in which the gaze was within an area of interest (see the preparation under 3.3.4)

4 Summary and outlook

Both remote eye trackers and eye tracking glasses offer the possibility of sending exact time synchronization signals via hardware interfaces. These can be received and recorded directly either by the amplifier of the biosignals or by their recording software. In this way, it is possible to use the software products of the different manufacturers and then combine the recorded data in a time-synchronized manner for joint analysis.

In addition to products from Tobii, the BiSigma Software Suite is also compatible with other eye trackers such as the Hiru remote eye tracker from Irisbond and the eye tracking glasses from Viewpointsystem.

In addition to the classic biosignals such as EEG, EMG, ECG and skin conductivity (EDA/GSR), the analysis of biosignals such as pupil width, facial expression/emotion recognition and voice analysis can also be evaluated. EEG recording can be carried out both classically with gel electrodes and via the dry EEG headset from Wearable Sensing, which enables quick and easy preparation of the test persons. For recording, however, we are also considering non-contact methods. For example, there are already experiments on how pulse measurement could be carried out using radar waves.

The BiSigma Software Suite is open for different hardware and software. Different formats can be imported. Existing data in CSV format can be imported and analyzed in the BiSigma Software Suite using the "Time Series Importer" in the "Import" menu. It is also possible to insert the triggers manually if required.

The export function allows you to export the data sets of each processing stage from the BiSigma Software Suite in ASCII format for further analysis in software tools such as SPSS and MATLAB® or further processing in Excel or statistical software such as R.

5 List of abbreviations

GSR	Galvanic Skin Response, galvanic skin reaction
EDA	Electrodermal activity
UX	User experience
EEG	Electroencephalography
FFT	Fast Fourier Transform

6 Bibliography

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