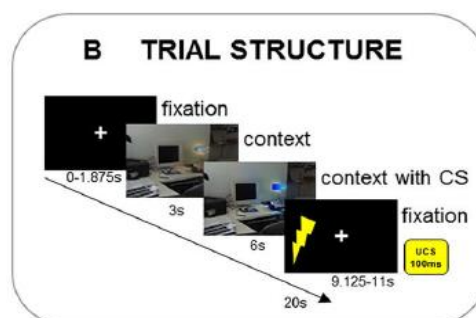


EDA-Analysis Documentation

This documentation serves the purpose to illustrate concrete steps to analyze EDA data from an exemplary study with the EDA-Analysis App from Tobias Otto. The App computes EDA results from raw data acquired with Biopac or Brainvision systems. Every study-specific step outlined below should be checked for each new study, if it is equally applicable or not.

Here are the study details for the exemplary fear conditioning data set, which are needed for the analyses. You can find the exemplary files along with two additional data sets in a separate folder.

In general, after the presentation of a fixation cross, a picture of a context appears for 3s, then, the conditioned stimulus (CS; lamplight either shining in blue or yellow) is presented within the same context for 6s. In case of a CS+ during fear acquisition training, an electrical stimulation (unconditioned stimulus, UCS) can appear immediately afterwards for 100ms (in 5 out of 8 trials).



Participants undergo different phases within the fear conditioning paradigm. During habituation, 2 CS+ and 2 CS- are shown. Without any break, fear acquisition training starts with the presentation of 8 CS+ and 8 CS-. The first and last CS+ trial within fear acquisition training is always coupled with the UCS. Within the remaining 6 CS+ trials, 3 trials are coupled with the UCS, thus, in total, 5 UCS applications take place.

habituation



acquisition



extinction



After a short break, extinction training starts in a new context with the presentation of 8 CS+ and 8 CS- trials, without any coupling with the UCS.

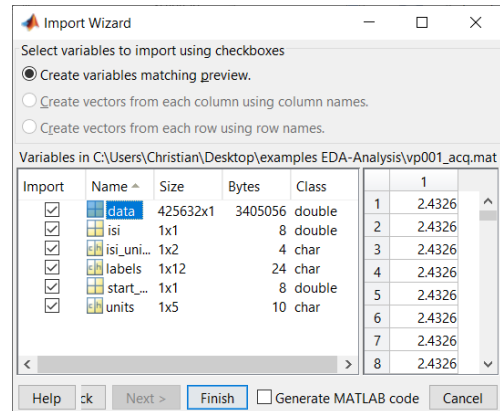
EDA responses should be analyzed in the following time windows (always with respect to trial start at context onset; please note that the onset of the EDA is usually delayed by 1s):

- response to the context: 1-3.99999s
- response to the CS: 4-9.49999s (in this case, 1s delay was reduced to 0,5s, since the response to the subsequent UCS can start earlier)
- response to the UCS: 9.5-13s

The respective time windows should be carefully selected for the specific experiment and the specific experimental phase!

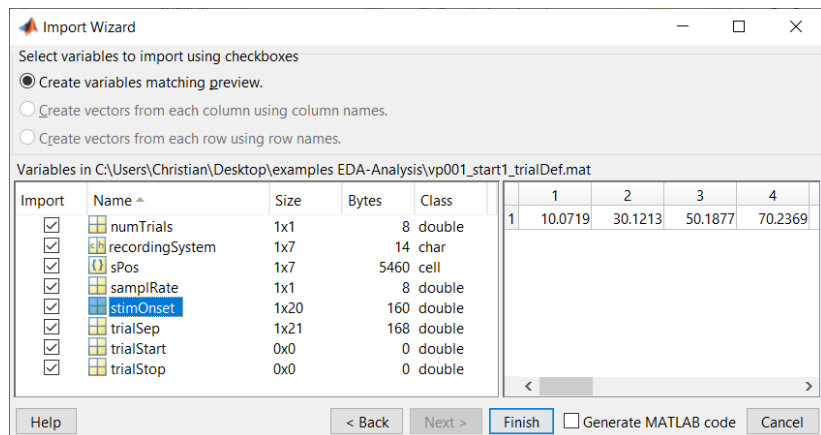
EDA data acquisition is realized in Acknowledge and results in two .mat files for each participant:

- **vp001_acq**: EDA data for habituation and fear acquisition training
- **vp001_ext**: EDA data for extinction training

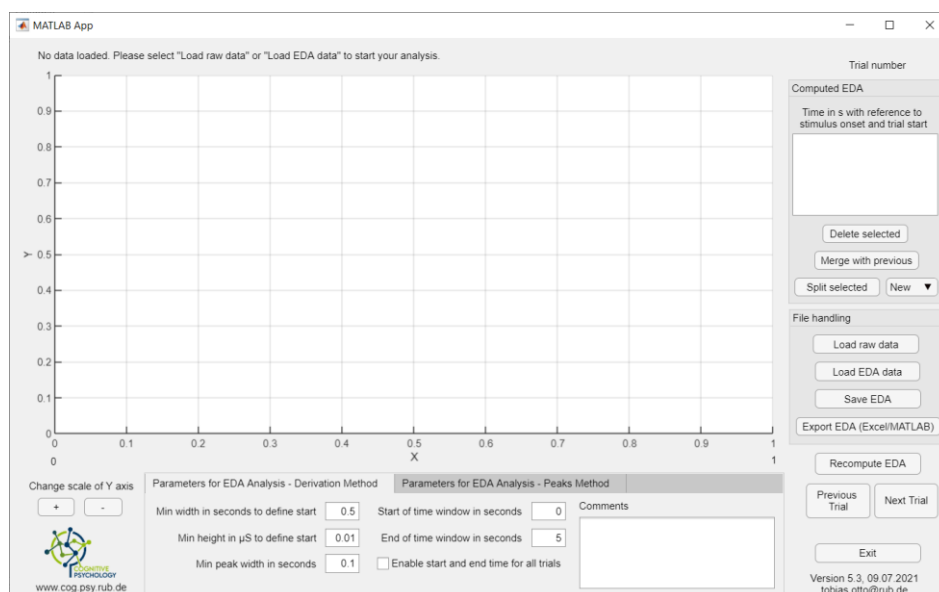
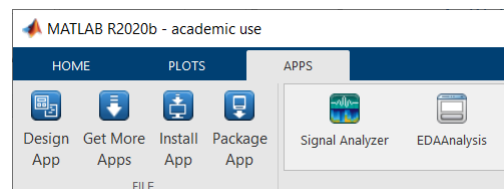


Presentation of the design is realized in MATLAB and results in two .mat files for each participant with details regarding trial timing to identify the stimulus onsets in the EDA data:

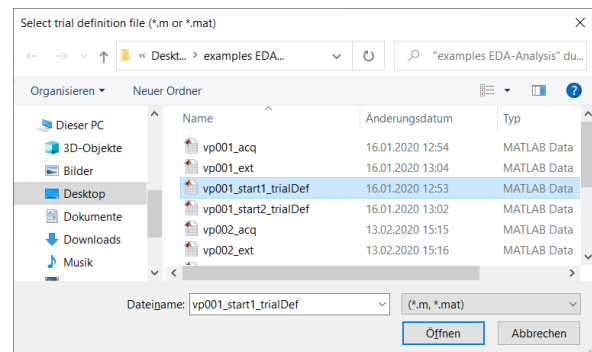
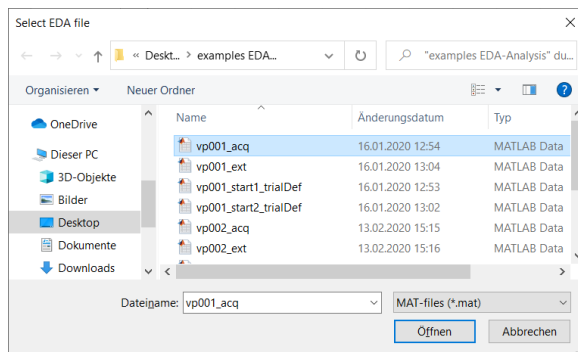
- **vp001_start1_trialDef**: EDA data for habituation and fear acquisition training
- **vp001_start2_trialDef**: EDA data for extinction training
- **note**: you have to take care that your specific trial definition file matches the needed requirements to be used



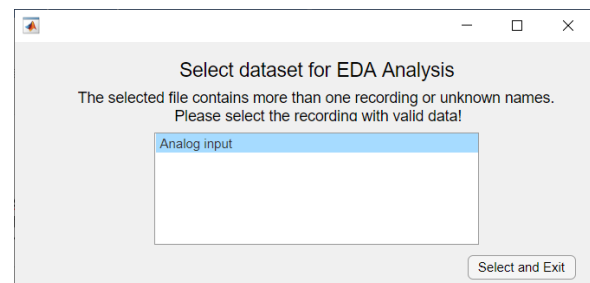
Once you have installed the EDA-Analysis App, it appears in Matlab under the heading APPS, a simple click opens the following GUI:



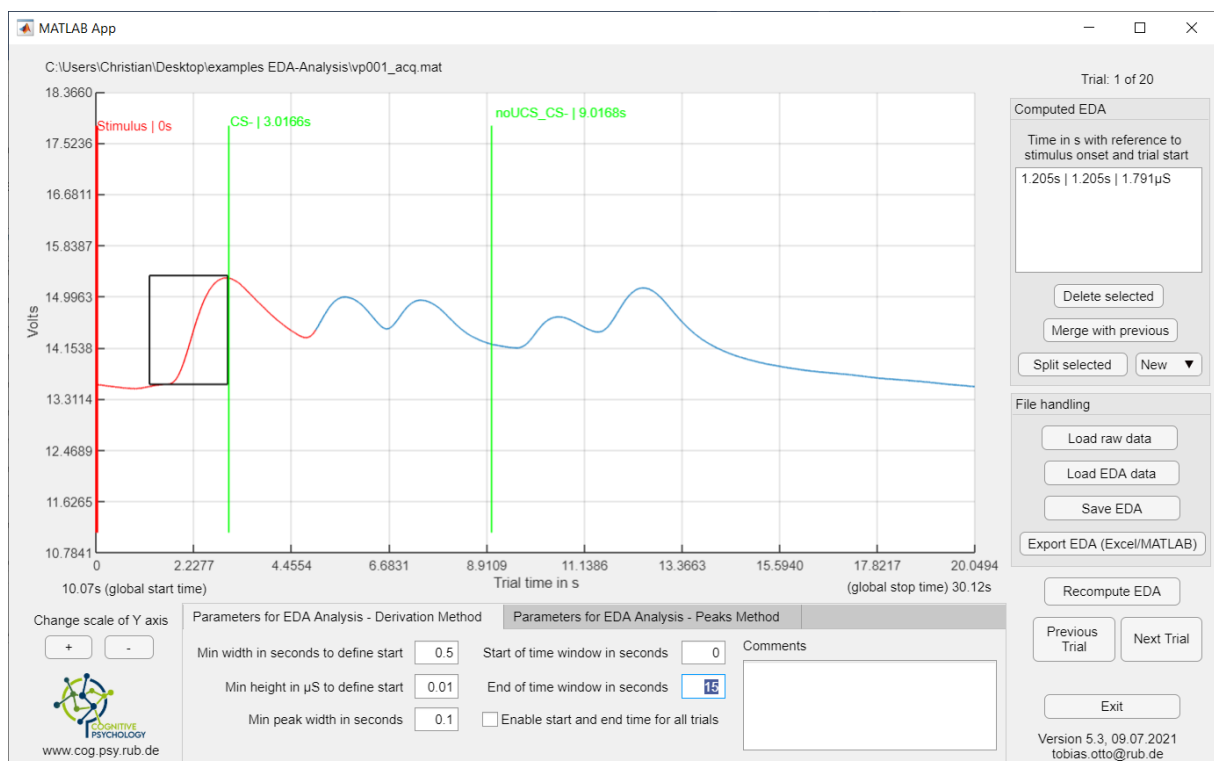
On the right side, under file handling, click on Load raw data and select in the new window your EDA raw data to be analyzed, in the exemplary case, vp001_acq. Click on open, then, you are prompted to select the respective trial definition file, in this case vp001_start1_trialDef, click on open.



In case you have different datasets saved in your raw data file, you have to select the appropriate input (EDA data) in the next window. Otherwise, simply click on select and exit while Analog input is selected.



The App then combines the information from the recorded EDA data with the information given for stimulus timing and stimulus names in the trial definition file:



Please make sure to adjust all following settings in the beginning for the specific experiment and ideally save them as a screenshot, in a separate documentation file or in the comments, so that you are able to remember them correctly at all times!

As default, the analysis time window is set to begin with 0s and end with 5s with respect to stimulus onset (in this case, context onset; red line, everything in the blue line is not analyzed). You can change this setting by using other values (in this case 15s for end of time window) in the tab Parameters for EDA Analysis – Derivation Method and then click on Recompute EDA.

With a click on Enable start and end time for all trials, these settings will be saved for all trials.

Please check if the other default values also apply for you before you start:

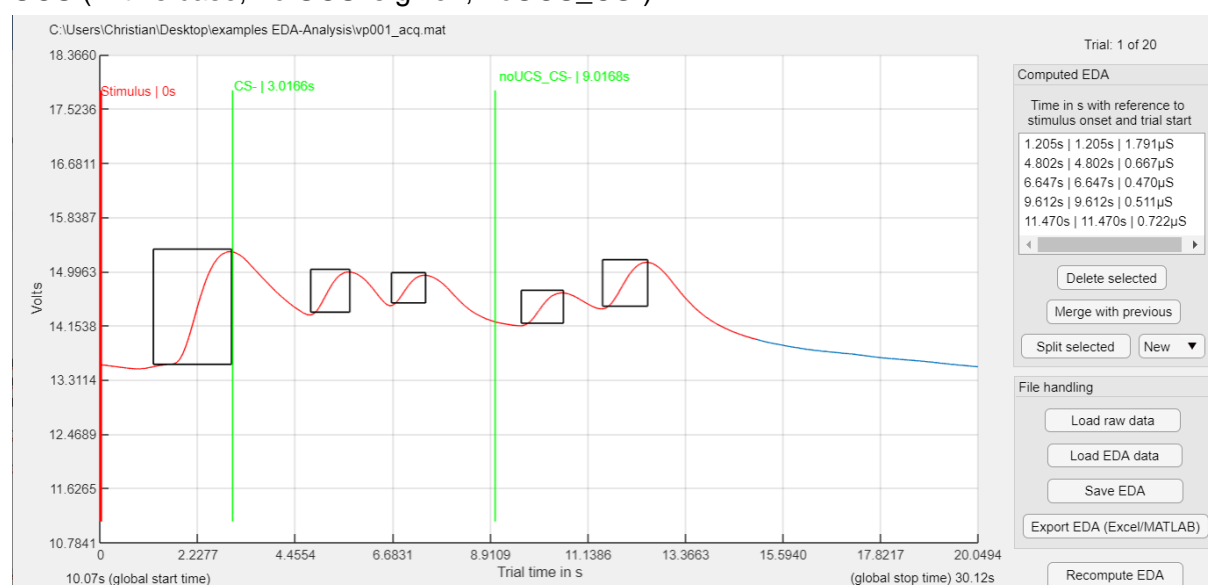
- Min width in s to define start: 0.5
- Min height in μS to define start: 0.01
- Min peak width in s: 0.1

You can change the scale of the y-axis anytime without changing the results with a simple click on + or – at the bottom left corner.

At the right upper corner, you can see the currently displayed trial (in this case Trial 1 of 20).

In the comments, you can insert any information you wish to include for the whole dataset, which will be consistently displayed in all trials.

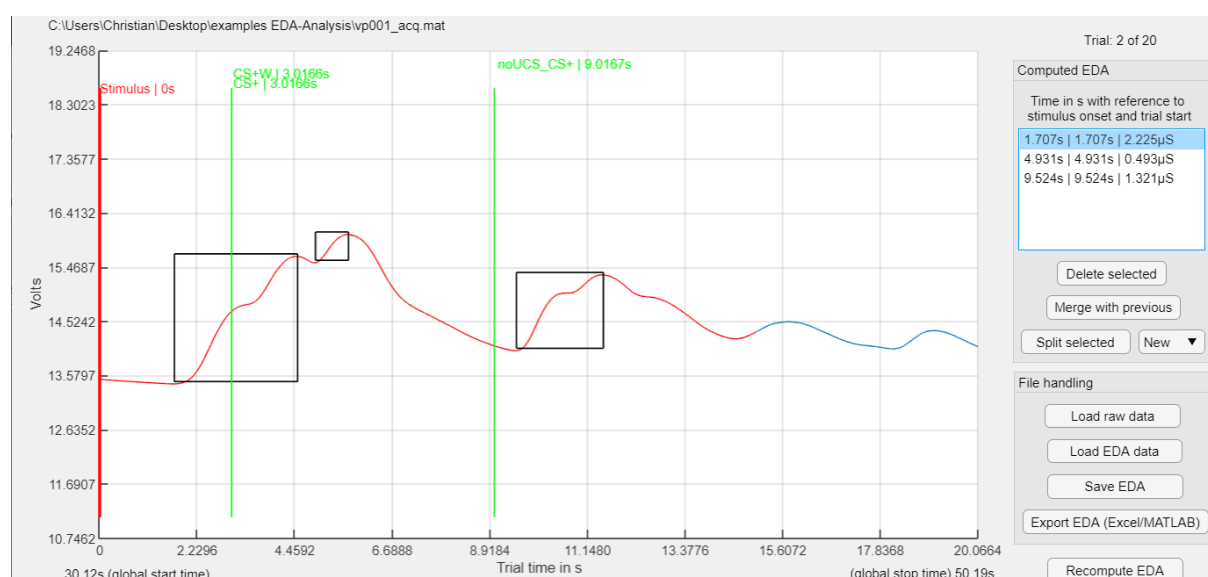
In the GUI, the red line represents the stimulus onset (in this case, context onset), the first green line the CS onset (in this case CS-) and the second green line the onset of the possible UCS (in this case, no UCS is given, noUCS_CS-).



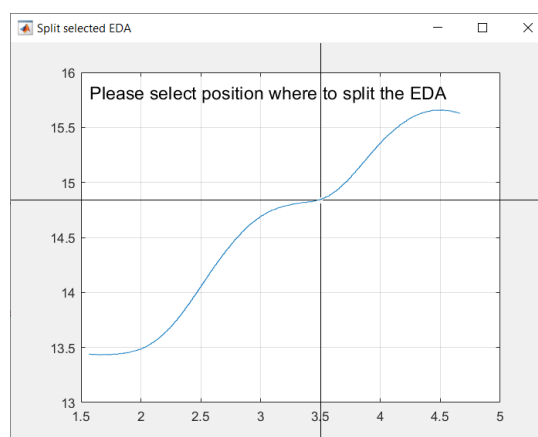
In the example, the implemented algorithm has identified five relevant EDA amplitudes in the given time window (0-15s), illustrated within the five boxes starting from the trough and ending with the peak of the respective response. Below the Trial number, you can find more details for the five computed EDA responses. For example, the first EDA response is characterized as beginning 1.205s after stimulus onset and trial start (identical in this case) with an amplitude of 1.791 μS .

With a click on Previous Trial or Next Trial at the right lower corner, you can switch trials and judge the computed EDA for every trial.

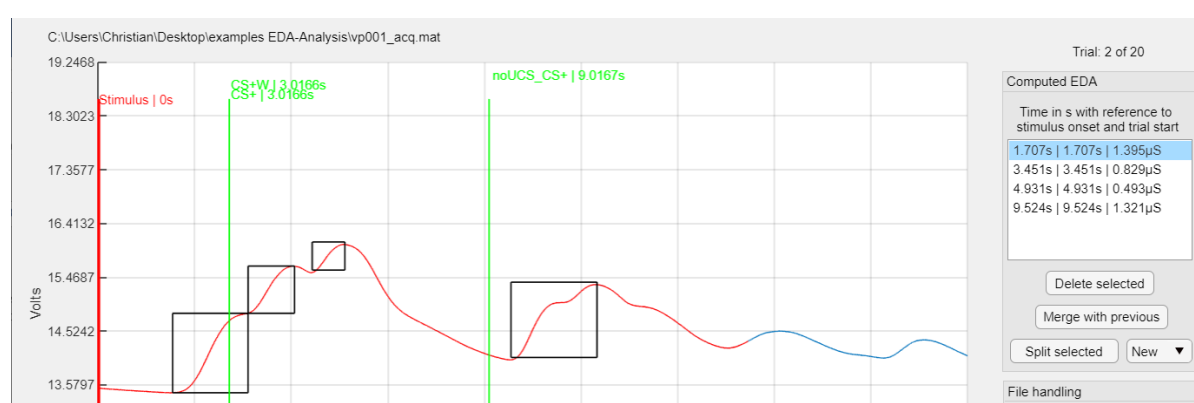
Let's have a look at trial 2, which does not seem so straightforward as trial 1:



The first (and third) response seems to actually consist of two superposed responses with no clear second minimal turning point, so that the algorithm cannot disentangle the two responses. In this case, you can split the EDA response by selecting the respective computed EDA at the upper right corner and then click on Split selected. You can use the cross appearing in a new window zooming in the respective response to indicate the point on the line where the response should be splitted. Usually, this should be the case at the saddle point, where the right curve turns into a left curve.



A click on the respective point on the line splits the response and the new responses are displayed together with the updated information on the computed EDA.



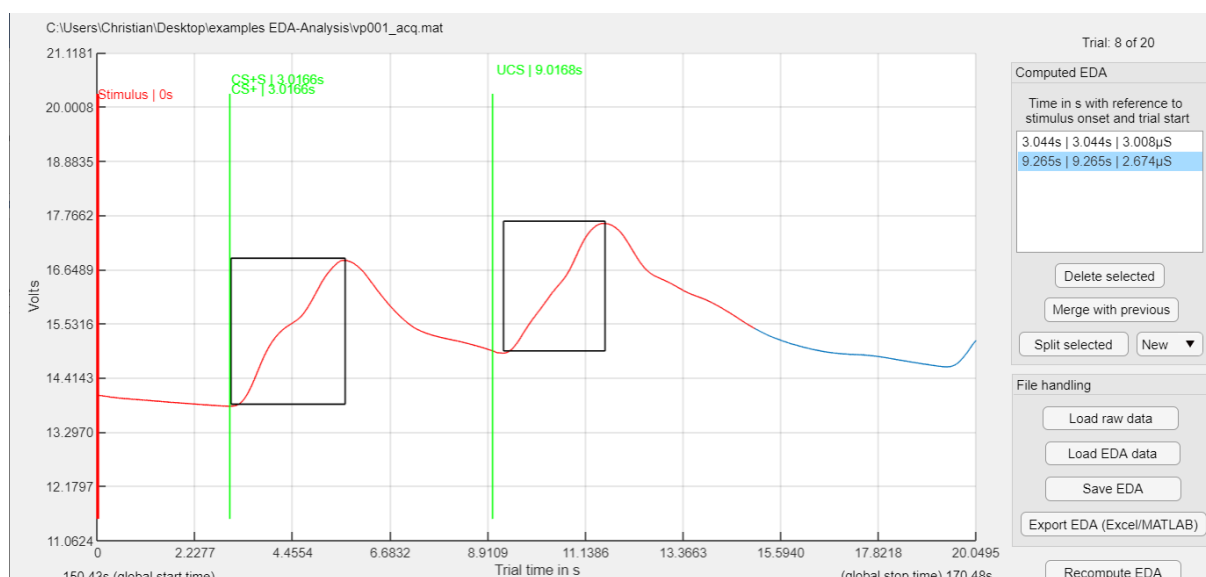
Next to Split selected, the option New should be used for any new complete analyses, the option Old for analyses started before July 2021. Using the option Old leads to a slightly different split of the response with a gap between offset and onset of the two responses. If you are not satisfied with your split, you can click on Recompute EDA leading to the initially computed EDA result for this trial.

Other available options are to delete the selected response (for example, in case of obvious movement-related distortions) or to merge the selected response with the previous response (usually not needed at all).

Attention! Splitting responses should be realized in a consistent way throughout the whole dataset and independent of CS trials.

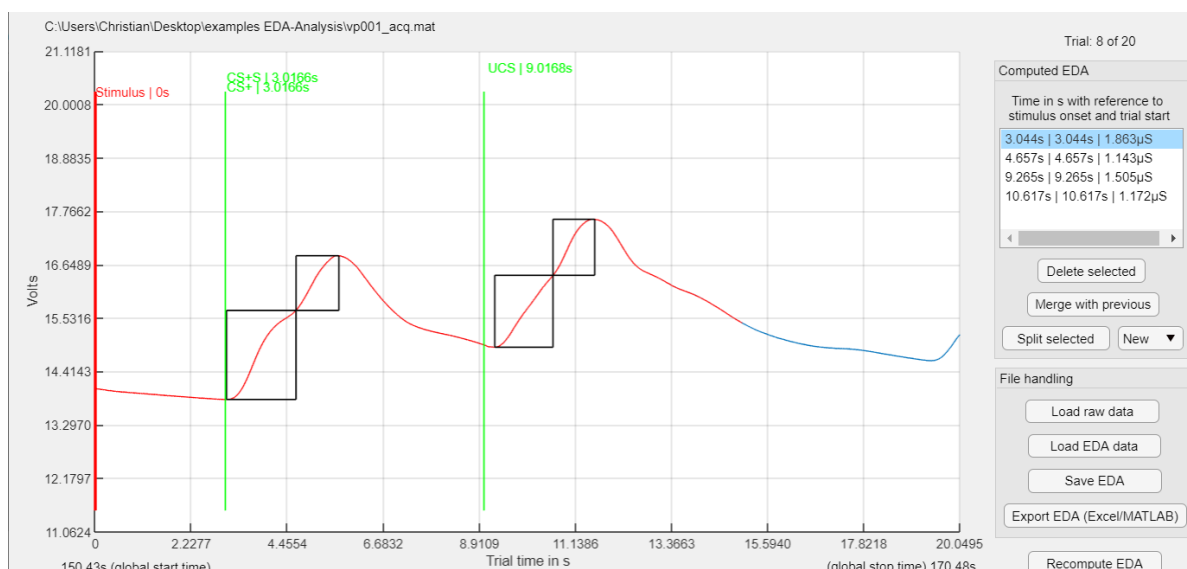
Since analysis time windows end at 13s, all responses starting after 13s can be neglected.

Another example from trial 8:



Both responses are problematic if you look at the onset and what they might represent. The first response starts at 3.044s and would be qualified as a response to the context (see time windows above). But this is again a superimposed response: within the response to the context, the response to the CS starts, which would be counted as response to the context as a whole if nothing was changed. The same applies for the second response, which is also superimposed, although not that obvious. But still the right curve turns into a left curve at some point. The second response starts at 9.265s and would be qualified as response to the CS (see time windows above). In this trial, a UCS was administered, without any change, no response to the UCS would be registered.

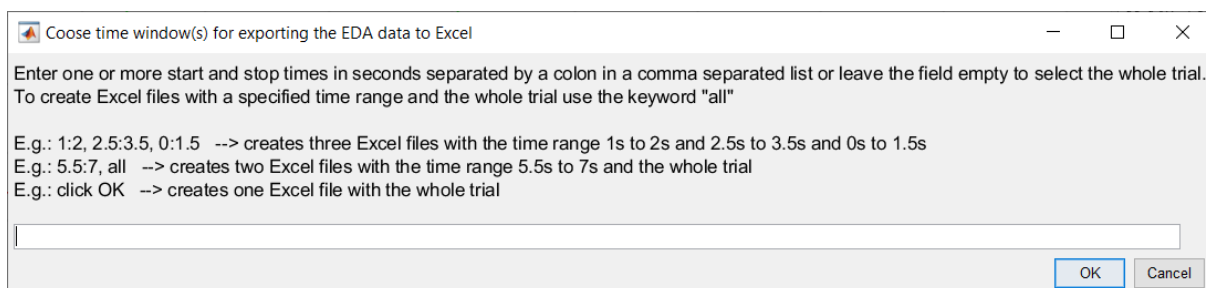
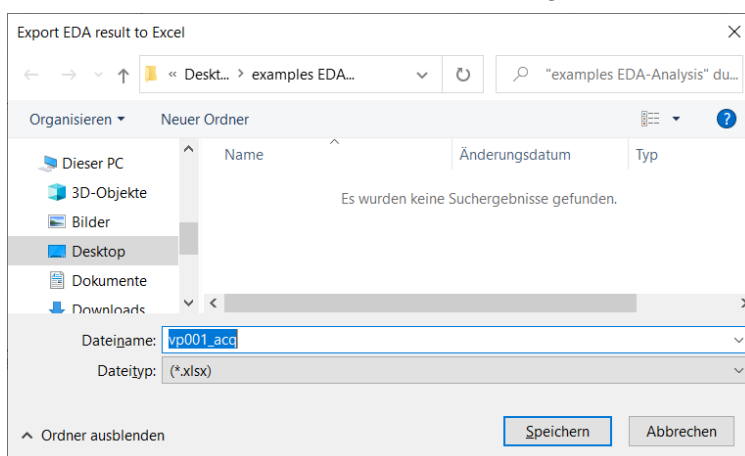
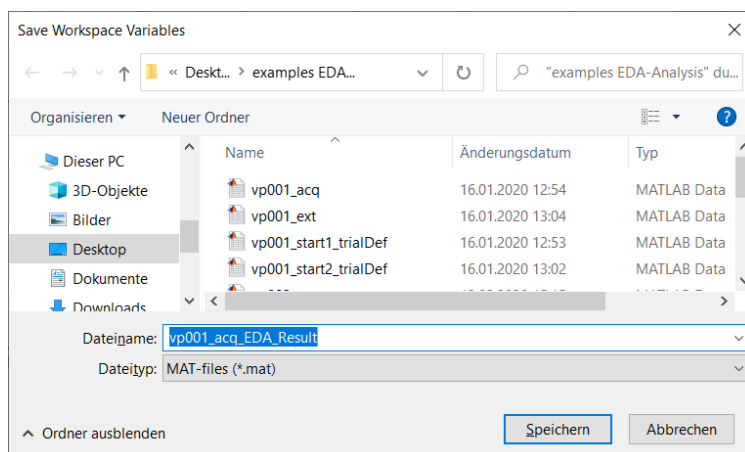
Thus, both responses should be splitted as indicated above, leading to this display:



If all trials are inspected, the changed EDA file should be saved by clicking on Save EDA in the section File handling on the right. A new window will appear with a suggestion of a new file name as .mat file, so that the raw data are not overwritten (simply extending the name with _EDA_Result). Click on Save and the respective EDA results will be saved.

You can also load EDA_Result files afterwards by using the option Load EDA data in the section File handling.

To export the EDA results with respect to the time windows, click on Export EDA (Excel/MATLAB). A new window will appear with a suggestion of a new file name as .xlsx file (using the file name of the EDA data). Click on Save leads to a new window, where the time windows for analyses should be inserted as indicated there.



For the exemplary data, this would be 1:3.99999, 4:9.49999, 9.5:13

A click on OK creates for each time window a new .xlsx and a new .mat file with the respective results. Within each time window, the **maximum response only** will be included in the results. In case of more than one response in a given time window, only the maximum response will be printed, be aware that this can be handled differently (e.g. some researchers always refer to the first response in a given time window, which is obviously not identical in each case with the maximum response).

| Name | Änderungsdatum | Typ | Größe |
|-------------------------|------------------|-----------------------|----------|
| vp001_acq_1s-4s | 22.07.2021 16:34 | Microsoft Excel-Ar... | 14 KB |
| vp001_acq_1s-4s.xlsx | 22.07.2021 16:34 | MATLAB Data | 3 KB |
| vp001_acq_4s-9.5s | 22.07.2021 16:34 | Microsoft Excel-Ar... | 15 KB |
| vp001_acq_4s-9.5s.xlsx | 22.07.2021 16:34 | MATLAB Data | 3 KB |
| vp001_acq_9.5s-13s | 22.07.2021 16:34 | Microsoft Excel-Ar... | 16 KB |
| vp001_acq_9.5s-13s.xlsx | 22.07.2021 16:34 | MATLAB Data | 3 KB |
| vp001_acq_EDA_Result | 22.07.2021 16:30 | MATLAB Data | 3.882 KB |
| vp003_ext | 18.02.2020 17:51 | MATLAB Data | 2.628 KB |
| vp003_acq | 18.02.2020 17:49 | MATLAB Data | 3.310 KB |
| vp003_start2_trialDef | 18.02.2020 17:43 | MATLAB Data | 2 KB |
| vp003_start1_trialDef | 18.02.2020 17:31 | MATLAB Data | 2 KB |
| vp002_ext | 13.02.2020 15:16 | MATLAB Data | 2.641 KB |
| vp002_acq | 13.02.2020 15:15 | MATLAB Data | 3.337 KB |
| vp002_start2_trialDef | 13.02.2020 15:12 | MATLAB Data | 2 KB |
| vp002_start1_trialDef | 13.02.2020 15:02 | MATLAB Data | 2 KB |
| vp001_ext | 16.01.2020 13:04 | MATLAB Data | 2.636 KB |

Opening the file `vp001_acq_4s-9.5s.xlsx` (or the respective `.mat` file), you can find three rows indicating trial number, the maximum EDA response and the time (with respect to stimulus onset) of the respective response (which should always be within the indicated time window 4-9.49999s). In different tabs, different compilations of the stimuli are given. In case only one trial order is used, the tab `Sheet1` should work: simply copy the second row (if you are interested in the maximum EDA response; if you are interested in the latency of this response occurring, then copy the third row) into your statistical analysis software and make there the classification of the trials to CS+ and CS-.

| | A | B | C | D | E | F | G | H | I | J | K |
|---|-----------|-------------|------------|-----------|-------------|------------|------------|------------|-----------|---|------------|
| 1 | Trial | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2 | maxEda | 0,666632612 | 0,49251206 | 1,3880996 | 0,744346225 | 0,80933211 | 1,07860746 | 0,41787268 | 1,5045166 | 0 | 1,72094355 |
| 3 | time(Stin | 4,802 | 4,931 | 4,388 | 4,802 | 4,409 | 5,639 | 4,735 | 9,265 | 0 | 4,642 |
| 4 | | | | | | | | | | | |

If you have different trial orders, you can still use this procedure, classification of trials to CS+ and CS- should then be realized for each participant and phase anew. But you can also make use of the different tabs given, for example, the tab `CS+_active` (`CS-_active`) displays all responses to the CS+ (CS-) in ascending trial order.

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|------------|------------|-------------|------------|-----------|------------|-------------|------------|------------|-------------|-----------|---|
| 1 | Trial | 2 | 4 | 5 | 8 | 10 | 12 | 13 | 15 | 17 | 19 | |
| 2 | maxEda | 0,49251206 | 0,744346225 | 0,80933211 | 1,5045166 | 1,72094355 | 0,840995239 | 1,79416308 | 2,16369629 | 0,289103572 | 1,9708505 | |
| 3 | time(CS+) | 1,9144421 | 1,7826327 | 1,3924302 | 6,2483986 | 1,625435 | 1,2493965 | 2,0614237 | 6,4594361 | 1,9844265 | 1,8154181 | |
| 4 | CS+ active | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 5 | | | | | | | | | | | | |

To stay within the example: Responses to the context (which does not change) are captured in the file `vp001_acq_1s-4s.xlsx` in tab `Sheet1`. Responses within the UCS time window are captured in the file `vp001_acq_9.5s-13s.xlsx` in the tabs `UCS_active` (five responses to the five UCS), `noUCS_CS+_active` (five responses to the UCS omission in CS+ trials, two from habituation, three from fear acquisition training) and `noUCS_CS-_active` (ten responses to the corresponding time window for the ten CS- trials, two from habituation, eight from fear acquisition training).

In the documentation folder, you can find in total three datasets (`vp001-vp003`) and the corresponding EDA results, so that you can try everything by yourself and compare your analyses with mine. Note: `Vp003`, trial 15 acq: second responses splitted, so that this obvious response to the UCS (starting a bit early with 9.404s) will be counted as UCS and not as large response to the CS.