

Application Note 251

N-Back Task Using the fNIR Optical Brain Imaging System with AcqKnowledge

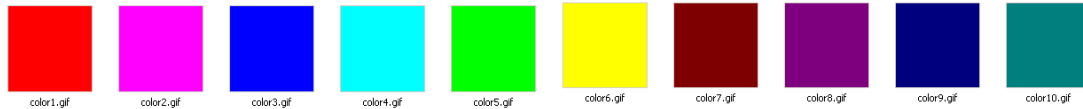
Running the task

1. Start the n-Back program. Do not press the spacebar yet, as this will initiate the experiment.



2. Adjust settings as desired before pressing the spacebar:
 - **n-Back setting**: choose from 0-back to 5-back condition
 - **Minimum interval**: this is the minimum time interval between the last response to a target question and the next question presentation
 - **Maximum interval**: this is the maximum time interval between the last response to a target question and the next question presentation. The actual presentation time of the question is randomly selected to be between the Minimum and Maximum interval, where after the minimum amount of time has elapsed, the probability of a target question increases linearly from 0 to 1 in X seconds, where $X = \text{Maximum Interval} - \text{Minimum Interval}$. This guarantees question presentation by the time of Maximum Interval and skews the probability density function towards the Minimum Interval.
 - **Number of trials**: This is the number of times the participant will be asked whether the current letter is the same as the one N letters ago. The program will exit automatically after the required trials have been completed. Setting this parameter effectively determines the duration of each condition.
 - **Participant name**: This is used to create a file with a report for the participant's responses. This feature is not implemented yet as of version 16 of the software but is planned for future versions. Currently, the information about the participant's performance can be extracted from the AcqKnowledge data record where all correct/incorrect responses as well as question presentation times are marked via digital triggers.
 - **Presentation(msec)**: Enter the duration (in msec) for presenting each letter/number/image/sound/object onscreen. The longer the duration, the more time participants will have to encode the new information.
 - **ISI(msec)**: Enter the interval in-between each presentation of a letter/number/image/sound/object onscreen (Inter Stimulus Interval). The longer this period, the more time the participant will have to repeat the sequence of letters to themselves.
 - **Target type**: Choose the target type here.
 - **Target instances**: Do not choose a number larger than 10, because there are only 10 instances. For each target type, these are the instances:

- **Letters:** A, B, C, D, E, F, G, H, I, J
- **Numbers:** 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- **Sounds:** 200 Hz, 300 Hz, 400 Hz, 500 Hz, 600 Hz, 700 Hz, 800 Hz, 900 Hz, 1000 Hz, 1100 Hz (all sounds are generated with Audacity)
- **Images:**

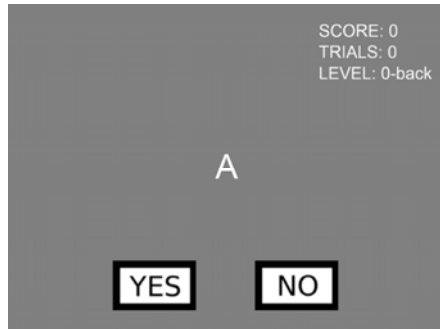


- **Objects:** Not yet implemented—future release may include simple animation sequences.

If 2 is set for the number of instances, and the target type is Letters, the letters A and B will be displayed. If the target type is Sounds, the sounds 200 Hz and 300 Hz will be played back. When choosing N for target instances, the first N items from the selected Target Type will be used in the program. The order is provided in the lists above.

Notes about the n-back program:

- When the screen turns grey, respond whether the letter currently displayed is the same as the letter displayed N letters back.



For example: if the sequence ABBBA was displayed and then the letter A was presented, respond with the following, depending on condition:

- If the condition is 0-back, respond with **YES** (this is like asking is the letter on the screen the letter on the screen?)
 - If the condition is 1-back, since the current letter is A and the sequence so far was “ABBBA”, respond with **YES**
 - If the condition is 2-back, since the current letter is A and the sequence so far was “ABBBA”, respond with **NO**
 - Use the same logic for the rest of the n-back conditions.
- SCORE in the upper right corner indicates the current percentage of correct responses. 50% is performance at chance. If participants perform at less than 80% for any condition, the data may not be good data.
 - TRIALS is a counter for the number of questions asked so far.
 - LEVEL is a reminder about the current n-back condition.
 - Responses can be indicated by mouse click (**YES** and **NO** buttons) or keyboard (‘y’ and ‘n’ keys).
 - When testing people, the task should feel more difficult for the participant with each higher n-back condition. But the participant should still be able to get at least 80% correct on any condition over 10 trials. It is best to have people practice the conditions first. Set the number of trials to 10 and start with the 0-back condition. Have them practice until they reach the following performance levels as a minimum:
 - 0-back: 100%
 - 1-back: 100%
 - 2-back: 90%
 - 3-back: 80%
 - 4-back: 70%

If necessary, adjust the PRESENTATION and ISI settings for each participant so they have enough time to encode information for each condition, but, at the same time, do not feel that the task is getting too easy. The default time intervals for PRESENTATION and ISI are simply suggested time intervals. The best strategy is to do test runs with each participant and fine tune the task to them. This should take no more than 20 minutes. Running the experiment should take another 20 minutes.

- Marker output from the n-back software:

| N-back Condition | PPT Code | | |
|------------------|-----------|------------------|--------------------|
| | New trial | Correct response | Incorrect response |
| 0 back | 1 | 70 | 140 |
| 1 back | 2 | 71 | 141 |
| 2 back | 4 | 72 | 142 |
| 3 back | 8 | 73 | 143 |
| 4 back | 16 | 74 | 144 |
| 5 back | 32 | 75 | 145 |

3. Start *AcqKnowledge* recording on digital channels 8-15, sample rate 200 Hz, duration 2 hours, append mode.
4. Start the COBI software and start the current device with the raw.clf template found in the COBI presets folder.
5. Make sure channels 3,4,5,6,11,12,13,14 are providing good readings.
6. Stop the device and load the biopac_demo.clf preset. Start the device, wait 20 seconds, run a baseline. After the baseline is complete, wait 5 sec, dip your head down for 3 sec, then back up. Make sure a good response is displayed on the screen.
7. Set up an experiment in COBI. Start the device and wait 20 seconds. Remain completely still and run the baseline.
8. Synchronize the COBI software and the *AcqKnowledge* data file:
 - Simultaneously hit **F9** to place a marker in *AcqKnowledge* and clicking Start recording in COBI.
 - An error of less than 2 seconds will not make a difference for the results—there may be some shift in the data but that's all.
9. Hit the spacebar to immediately start the n-back experiment.
10. After the program completes its run for the selected condition, simply start the program again, select the new condition and hit the spacebar (COBI and *AcqKnowledge* can continue running). The following sequence of tasks is recommended:
 - 1-back, 2-back, 3-back, 30 sec pause
 - 3-back, 1-back, 2-back, 30 sec pause
 - 2-back, 3-back, 1-back, end

Data import and analysis

- Open the **.nir.oxy** file for the experiment in Excel/Open Office.
 - The oxy file is found in the COBI program folder and has a **nir.oxy** extension. It can be opened by Excel/Open Office—start the spreadsheet application first and open the file from there.
 - The “Start Time” column, which contains the time of each sample point, is the first column in the file:

| | A | B | C | D | E | F | G | H |
|----|--------------------------|--------------------------|--------------|-------|-------|------|-------|-------|
| 1 | fnirUSB.dll Hb/HbO2 file | | | | | | | |
| 2 | Start Time: | Wed Mar 17 15:45:24 2010 | | | | | | |
| 3 | | | | | | | | |
| 4 | Start Code: | 601881.55 | 601905328.00 | | | | | |
| 5 | Freq Code: | 2793250000.00 | | | | | | |
| 6 | Current: | 7.00 | | | | | | |
| 7 | Gains: | 20.00 | | | | | | |
| 8 | Other: | none | | | | | | |
| 9 | 71.61 | -0.11 | -0.01 | 0.06 | 0.02 | 0.19 | 0.41 | -0.31 |
| 10 | 72.11 | -0.22 | -0.19 | 0.00 | -0.15 | 0.06 | 0.14 | -0.40 |
| 11 | 72.61 | -0.05 | -0.24 | 0.12 | -0.22 | 0.27 | -0.02 | -0.18 |
| 12 | 73.11 | 0.02 | -0.08 | 0.09 | -0.16 | 0.28 | 0.04 | 0.03 |
| 13 | 73.61 | -0.06 | -0.21 | -0.01 | -0.25 | 0.13 | -0.21 | 0.05 |
| 14 | 74.11 | 0.08 | 0.00 | 0.09 | -0.11 | 0.28 | -0.06 | 0.18 |
| 15 | 74.61 | -0.08 | -0.07 | 0.01 | -0.17 | 0.06 | -0.22 | -0.02 |
| 16 | 75.11 | 0.13 | -0.04 | 0.18 | -0.10 | 0.32 | -0.28 | 0.16 |
| 17 | 75.67 | 0.18 | 0.09 | 0.20 | 0.03 | 0.27 | -0.14 | 0.07 |
| 18 | 76.17 | 0.06 | -0.20 | 0.15 | -0.15 | 0.19 | -0.44 | 0.00 |
| 19 | 76.67 | 0.01 | 0.04 | 0.09 | 0.05 | 0.14 | -0.13 | -0.17 |

- Calculate the average actual sample rate. This is the sample rate to be used when the file is imported in AcqKnowledge.
 - Add an extra column with delta-t in Excel and averaging that. Insert a new column next to the time column for calculating the delta T between sample points.
 - Use the expression in box B10 and copy and paste that box for all the B column entries (shortcut: copy the B10 box and then select all the B column cells and paste via Ctrl+V)

| | A | B | C | D | E | F | G |
|----|--------------------------|--------------------------|--------------|-------|-------|-------|------|
| 1 | fnirUSB.dll Hb/HbO2 file | | | | | | |
| 2 | Start Time: | Wed Mar 17 15:45:24 2010 | | | | | |
| 3 | | | | | | | |
| 4 | Start Code: | 601881.55 | 601905328.00 | | | | |
| 5 | Freq Code: | 2793250000.00 | | | | | |
| 6 | Current: | 7.00 | | | | | |
| 7 | Gains: | 20.00 | | | | | |
| 8 | Other: | none | | | | | |
| 9 | 71.61 | -0.11 | -0.01 | 0.06 | 0.02 | 0.19 | |
| 10 | 72.11 | =A10-A9 | -0.22 | -0.19 | 0.00 | -0.15 | 0.06 |
| 11 | 72.61 | | -0.05 | -0.24 | 0.12 | -0.22 | 0.27 |
| 12 | 73.11 | | 0.02 | -0.08 | 0.09 | -0.16 | 0.28 |
| 13 | 73.61 | | -0.06 | -0.21 | -0.01 | -0.25 | 0.13 |
| 14 | 74.11 | | 0.08 | 0.00 | 0.09 | -0.11 | 0.28 |
| 15 | 74.61 | | -0.08 | -0.07 | 0.01 | -0.17 | 0.06 |
| 16 | 75.11 | | 0.13 | -0.04 | 0.18 | -0.10 | 0.32 |
| 17 | 75.67 | | 0.18 | 0.09 | 0.20 | 0.03 | 0.27 |
| 18 | 76.17 | | 0.06 | -0.20 | 0.15 | -0.15 | 0.19 |
| 19 | 76.67 | | 0.01 | 0.04 | 0.09 | 0.05 | 0.14 |

| | A | B | C | D | E | F | G |
|----|--------|-------|-------|-------|-------|-------|-------|
| 7 | Gains: | | 20.00 | | | | |
| 8 | Other: | | none | | | | |
| 9 | | 71.61 | -0.11 | -0.01 | 0.06 | 0.02 | 0.19 |
| 10 | | 72.11 | -0.22 | -0.19 | 0.00 | -0.15 | 0.06 |
| 11 | | 72.61 | | -0.24 | 0.12 | -0.22 | 0.27 |
| 12 | | 73.11 | | -0.08 | 0.09 | -0.16 | 0.28 |
| 13 | | 73.61 | | -0.21 | -0.01 | -0.25 | 0.13 |
| 14 | | 74.11 | | 0.00 | 0.09 | -0.11 | 0.28 |
| 15 | | 74.61 | | -0.07 | 0.01 | -0.17 | 0.06 |
| 16 | | 75.11 | | -0.04 | 0.18 | -0.10 | 0.32 |
| 17 | | 75.67 | | 0.09 | 0.20 | 0.03 | 0.27 |
| 18 | | 76.17 | | -0.20 | 0.15 | -0.15 | 0.19 |
| 19 | | 76.67 | | 0.04 | 0.09 | 0.05 | 0.14 |
| 20 | | 77.17 | | 0.27 | 0.05 | 0.23 | 0.06 |
| 21 | | 77.67 | | -0.07 | 0.01 | 0.00 | 0.02 |
| 22 | | 78.17 | | 0.07 | 0.08 | 0.15 | 0.11 |
| 23 | | 78.67 | | 0.19 | 0.05 | 0.23 | 0.12 |
| 24 | | 79.17 | | 0.20 | -0.15 | 0.24 | -0.21 |
| 25 | | 79.67 | | -0.16 | -0.02 | -0.01 | 0.01 |

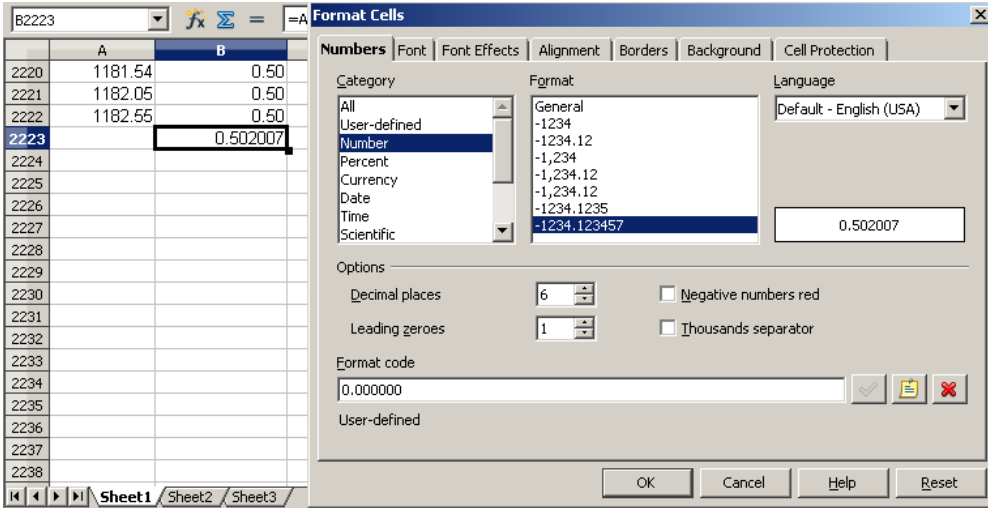
| | A | B | C | D | E | F | G |
|----|--------|-------|-------|-------|-------|-------|-------|
| 7 | Gains: | | 20.00 | | | | |
| 8 | Other: | | none | | | | |
| 9 | | 71.61 | -0.11 | -0.01 | 0.06 | 0.02 | 0.19 |
| 10 | | 72.11 | 0.50 | -0.19 | 0.00 | -0.15 | 0.06 |
| 11 | | 72.61 | 0.50 | -0.05 | -0.24 | 0.12 | -0.22 |
| 12 | | 73.11 | 0.50 | 0.02 | -0.08 | 0.09 | -0.16 |
| 13 | | 73.61 | 0.50 | -0.06 | -0.21 | -0.01 | -0.25 |
| 14 | | 74.11 | 0.50 | 0.08 | 0.00 | 0.09 | -0.11 |
| 15 | | 74.61 | 0.50 | -0.08 | -0.07 | 0.01 | -0.17 |
| 16 | | 75.11 | 0.50 | 0.13 | -0.04 | 0.18 | -0.10 |
| 17 | | 75.67 | 0.56 | 0.18 | 0.09 | 0.20 | 0.03 |
| 18 | | 76.17 | 0.50 | 0.06 | -0.20 | 0.15 | -0.15 |
| 19 | | 76.67 | 0.50 | 0.01 | 0.04 | 0.09 | 0.05 |
| 20 | | 77.17 | 0.50 | -0.03 | 0.27 | 0.05 | 0.23 |
| 21 | | 77.67 | 0.50 | -0.08 | -0.07 | 0.01 | 0.00 |
| 22 | | 78.17 | 0.50 | 0.00 | 0.07 | 0.08 | 0.15 |
| 23 | | 78.67 | 0.50 | -0.03 | 0.19 | 0.05 | 0.23 |
| 24 | | 79.17 | 0.50 | -0.29 | 0.20 | -0.15 | 0.24 |
| 25 | | 79.67 | 0.50 | -0.11 | -0.16 | -0.02 | -0.01 |

- Go to the last row of column B and set up an averaging expression:

| | A | B | C | D | E | F | G |
|------|---------|---------------------|-------------------|------|-------|------|-------|
| 2215 | 1179.04 | 0.50 | -1.17 | 3.12 | -0.52 | 2.11 | -0.58 |
| 2216 | 1179.54 | 0.50 | -1.04 | 3.06 | -0.37 | 2.12 | -0.50 |
| 2217 | 1180.04 | 0.50 | -1.21 | 3.30 | -0.49 | 2.33 | -0.58 |
| 2218 | 1180.54 | 0.50 | -1.12 | 2.53 | -0.39 | 1.81 | -0.48 |
| 2219 | 1181.04 | 0.50 | -1.16 | 2.78 | -0.43 | 2.02 | -0.48 |
| 2220 | 1181.54 | 0.50 | -1.26 | 3.05 | -0.51 | 2.24 | -0.57 |
| 2221 | 1182.05 | 0.50 | -1.22 | 2.43 | -0.47 | 1.80 | -0.56 |
| 2222 | 1182.55 | 0.50 | 2213 R x 1 C 1.18 | 2.58 | -0.48 | 1.96 | -0.51 |
| 2223 | | =AVERAGE(B10:B2222) | | | | | |
| 2224 | | | | | | | |

- Change the cell formatting to display at least 6 significant figures.

| | A | B | C | D | E | F | G |
|------|---------|------|-------|------|-------|------|-------|
| 2220 | 1181.54 | 0.50 | -1.26 | 3.05 | -0.51 | 2.24 | -0.57 |
| 2221 | 1182.05 | 0.50 | -1.22 | 2.43 | -0.47 | 1.80 | -0.56 |
| 2222 | 1182.55 | 0.50 | -1.18 | 2.58 | -0.48 | 1.96 | -0.51 |
| 2223 | | 0.50 | | | | | |
| 2224 | | | | | | | |
| 2225 | | | | | | | |
| 2226 | | | | | | | |
| 2227 | | | | | | | |
| 2228 | | | | | | | |
| 2229 | | | | | | | |
| 2230 | | | | | | | |
| 2231 | | | | | | | |
| 2232 | | | | | | | |
| 2233 | | | | | | | |
| 2234 | | | | | | | |
| 2235 | | | | | | | |
| 2236 | | | | | | | |
| 2237 | | | | | | | |
| 2238 | | | | | | | |



- The number obtained in this example is 0.502007 seconds between sample points. Write the result down as it will be required when importing data in AcqKnowledge.

Note: The sample rate should always be 2 Hz. This means there should be 0.5 seconds exactly between sample points. On some computers, due to the operation of the USB bus, there can be timing inaccuracies. This part of the analysis process is designed to help deal with such inaccuracies.

3. Copy just the data columns (excluding time) and paste them in a text file. Save this text file.

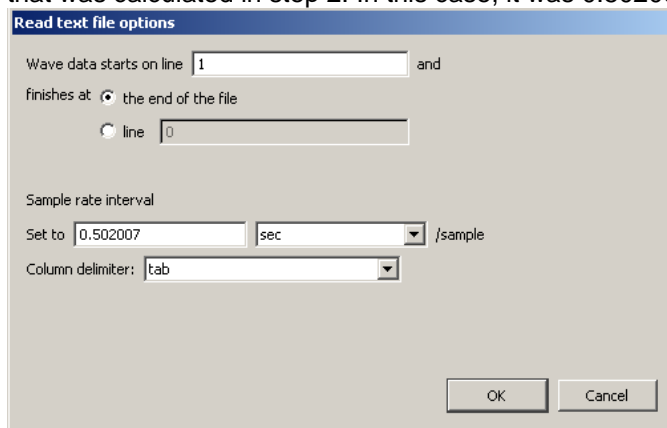
| Start Time | End Time | Start Code | Count | Units | Other |
|------------|----------|------------|-------|-------|-------|
| 7:00 | 7:00 | 7:00 | 7:00 | 7:00 | 7:00 |
| 7:00 | 7:00 | 7:00 | 7:00 | 7:00 | 7:00 |

| Time | Channel 1 | Channel 2 | Channel 3 | Channel 4 | Channel 5 | Channel 6 | Channel 7 | Channel 8 | Channel 9 | Channel 10 | Channel 11 | Channel 12 | Channel 13 | Channel 14 | Channel 15 | Channel 16 | Channel 17 | Channel 18 | Channel 19 | Channel 20 |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.01 | 0.11 | 0.01 | 0.06 | 0.02 | 0.19 | 0.14 | 0.51 | 0.19 | 0.20 | 0.12 | 0.06 | 0.40 | 0.31 | 0.84 | 0.27 | 0.49 | 0.27 | 0.61 | 0.29 | 0.46 |

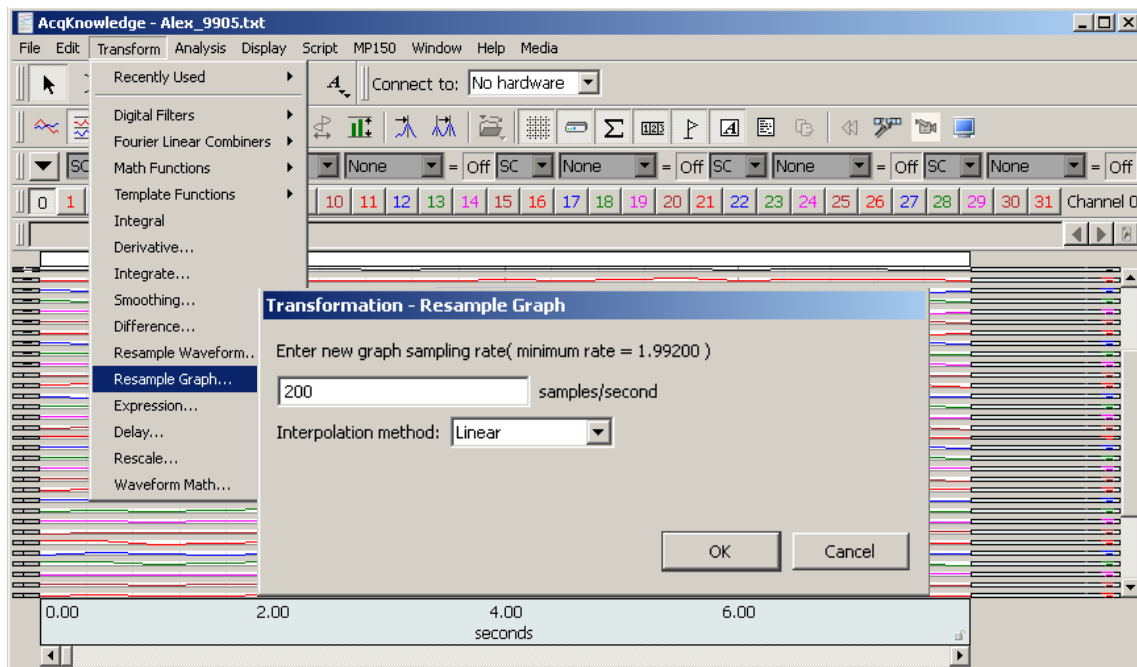
| Channel 1 | Channel 2 | Channel 3 | Channel 4 | Channel 5 | Channel 6 | Channel 7 | Channel 8 | Channel 9 | Channel 10 | Channel 11 | Channel 12 | Channel 13 | Channel 14 | Channel 15 | Channel 16 | Channel 17 | Channel 18 | Channel 19 | Channel 20 |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| -1.12 | 3.09 | -0.30 | 2.16 | -0.57 | 3.58 | -0.33 | 2.36 | -0.48 | 3.01 | -0.40 | 1.18 | -0.67 | 2.27 | -0.20 | 0.00 | | | | |
| -1.11 | 3.46 | -0.38 | 2.44 | -0.64 | 3.92 | -0.39 | 2.68 | -0.25 | 3.30 | -0.16 | 1.36 | -0.52 | 2.51 | -0.03 | 0.00 | | | | |
| -1.12 | 2.87 | -0.30 | 2.02 | -0.60 | 3.34 | -0.37 | 2.17 | -0.60 | 2.91 | -0.54 | 1.06 | -0.84 | 2.23 | -0.28 | 0.00 | | | | |

4. Import the text file into *AcqKnowledge* as tab-delimited text.

- Choose File > Open.
- Specify Text as the file type.
- Select the file that was just created.
- A dialog will be generated—configure it as shown in the screenshot below, substituting the sample rate that was calculated in step 2. In this case, it was 0.502007.



5. Resample the resulting file to the same sample rate as the *AcqKnowledge* file that has all the digital triggers (200 Hz) and save this as an *AcqKnowledge* file. Let's call this file COBI_DATA.

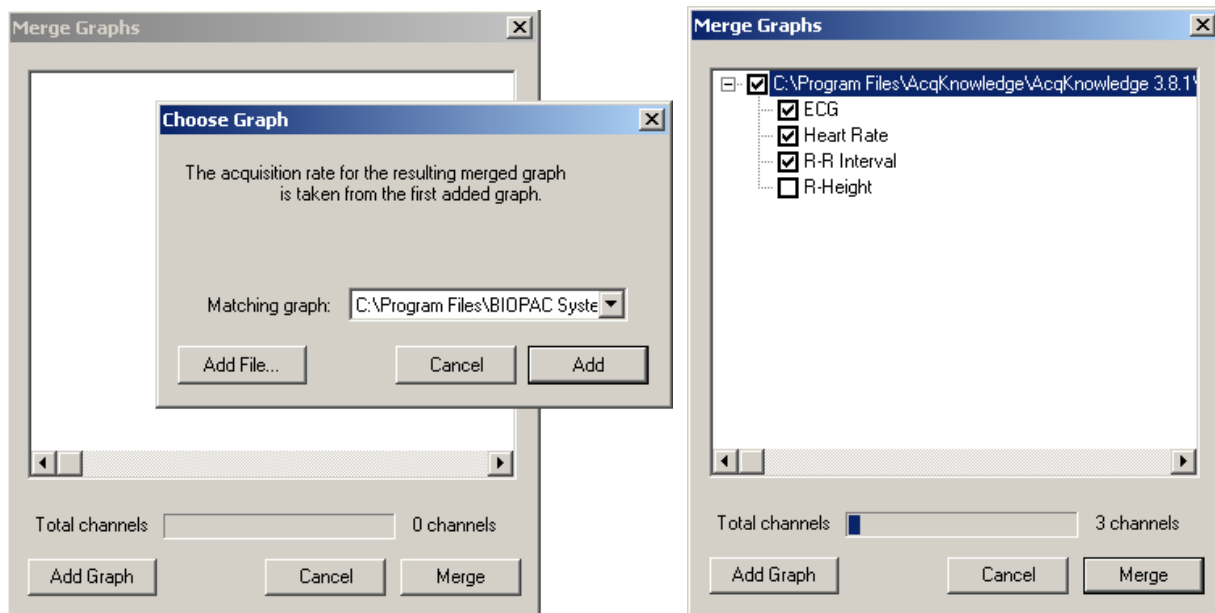


6. Open the *AcqKnowledge* file that has all the digital markers and delete all the data prior to the marker that was placed when the COBI acquisition started (via Clear all). Save that file. Let's call this file MARKER_DATA
7. Merge the two files, COBI_DATA and MARKER_DATA in *AcqKnowledge*:

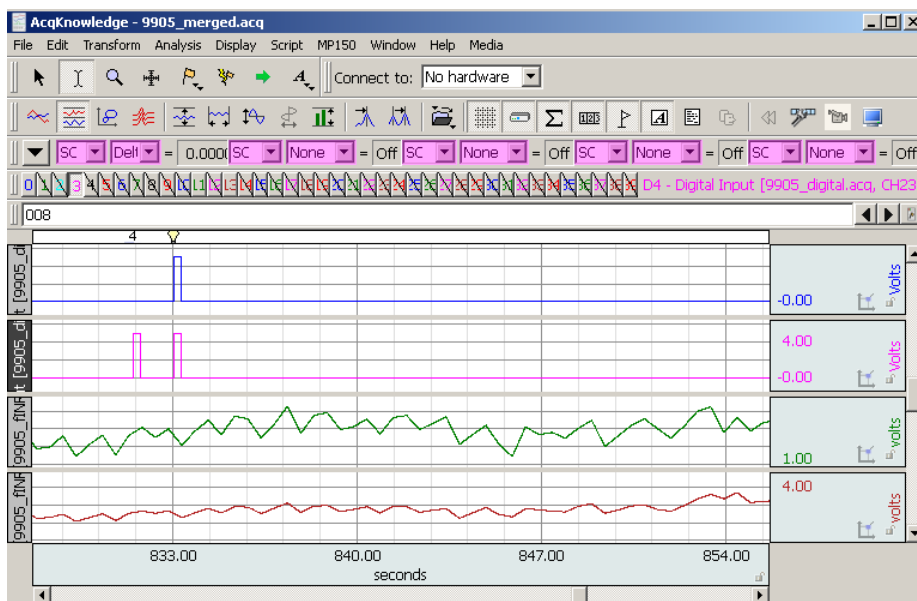
- Merge Graphs can combine up to 60 channels from multiple graph files acquired with the same acquisition rate into one merged graph file.

Note Merge Graphs requires *AcqKnowledge* to allocate additional memory and then load the data into memory; when this operation is executed on large data files, the application may crash—on Windows OS, the resulting file size of a merge should be less than 2 GB; data files greater than 2 GB can be opened, but edit, transformation and analysis operation cannot be performed.

- Select Edit > Merge Graphs to generate the Merge Graphs dialog.
- Click Add Graph to generate the Choose Graph dialog.
- Choose a file to add to the merge.
 - “Add” the “Matching graph” listed (this pull-down menu includes all open files with the same acquisition rate)
 - “Add File...” to browse and select a file that is not already open
- Adjust the selection for individual channels if desired.
 - Click the “+” to list individual channels in the graph file.
 - Toggle the checkbox to add or remove the associated channel/graph file.
 - You cannot delete a file name from the list, but you can remove it from the merge.
- Repeat as desired for multiple files.
- Click Merge and wait (you can check the status in the Total Channels bar).
- Save the merged file.

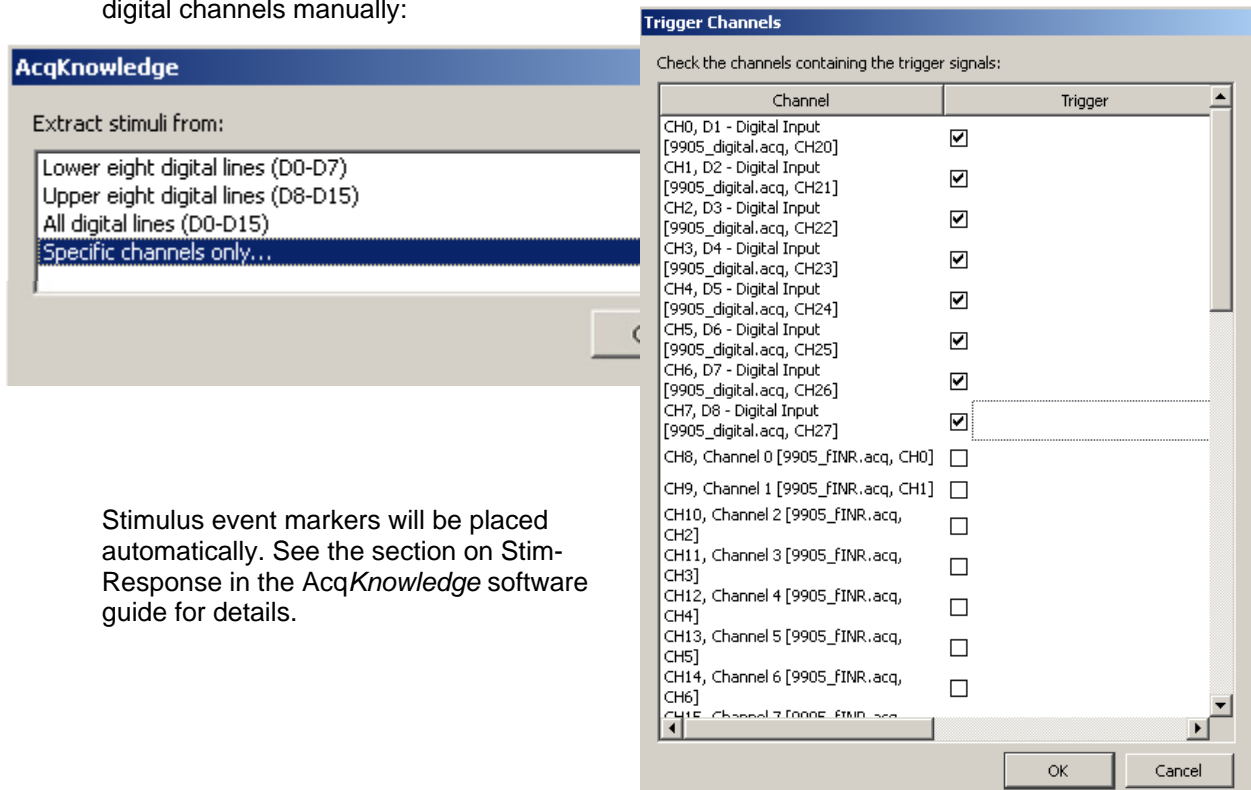


At this point the resulting merged file will have all the digital markers and the COBI data (as well as any physiological data that may have been recorded). In the following screenshot, there are 8 digital channels, 1 analog channel and 32 channels from COBI (16 oxy and 16 deoxy channels). Note that all channels except for two of the digital and two of the COBI channels are hidden so that the screenshot is easier to view:



8. Obtain the average response to each of the different stimuli.

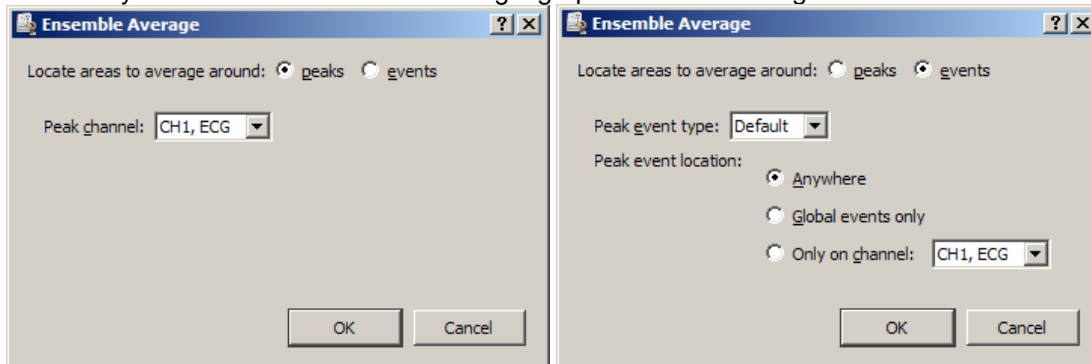
- The stimuli can be scored automatically via Analysis > Stim-Response > Digital Input to Stim Events function.
- In the merged file it is likely that the digital channels will no longer have the same channel numbers AcqKnowledge expects for digital channels; use the **Specific channels only** option and specify the digital channels manually:



Stimulus event markers will be placed automatically. See the section on Stim-Response in the AcqKnowledge software guide for details.

9. Perform Ensemble Averaging based on the markers that were just placed.

Ensemble Average assists in performing offline averaging. Offline averaging produces an average waveform from a number of cycles, also known as an *ensemble average*. Averages of multiple channels can be extracted simultaneously and be consolidated into a single graph window showing the results.

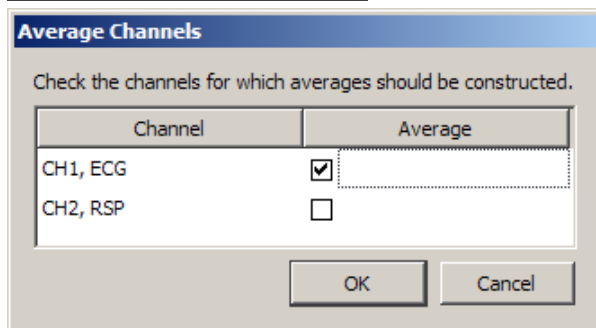
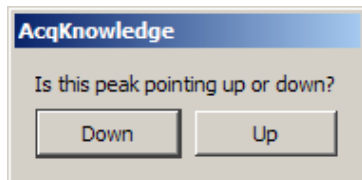
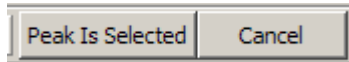


- This option provides two methods for locating individual members of the ensemble.

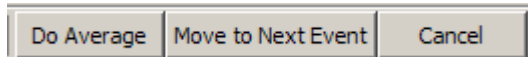
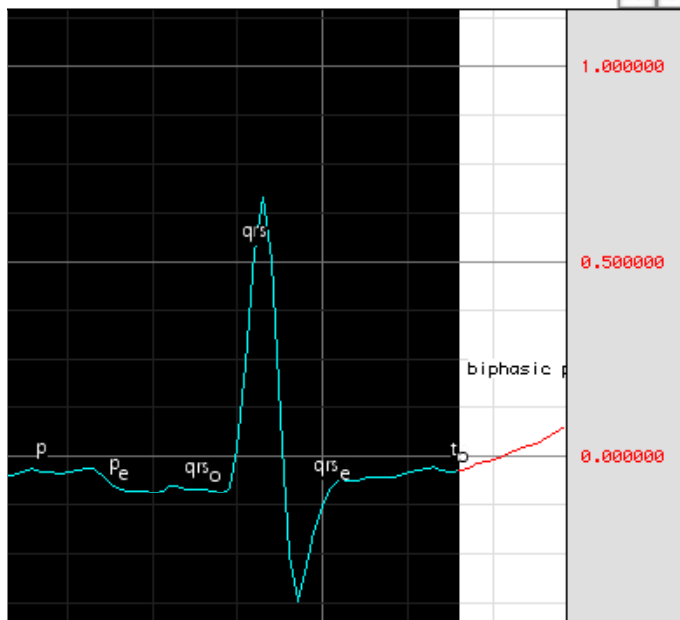
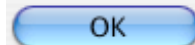
Peaks Data-driven peak detection with positive or negative peaks in the data. This method automatically derives appropriate threshold levels from a user-selected peak and is useful for constructing averages keyed to periodic signals with strong spikes, such as ECG.

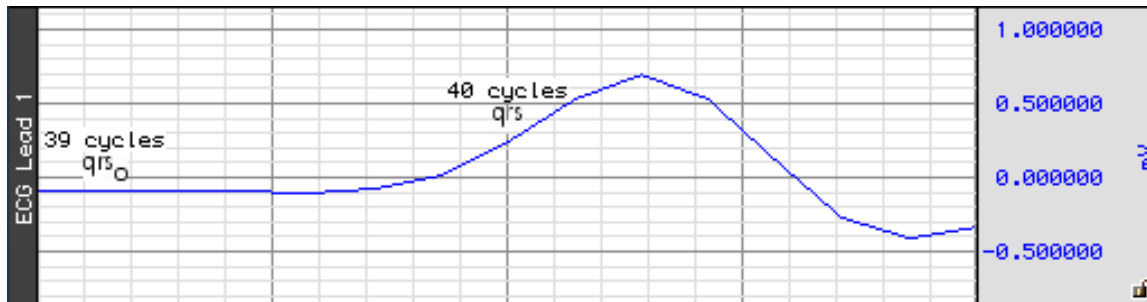
Events Place members of the ensemble surrounding events in the waveform. Events must be previously defined by the user, either manually or through another automated process. This method is useful for constructing averages keyed to any types of events in a graph.

- Include at least 10-12 seconds of data after each marker because the response recorded by the fNIR system is hemodynamic and slow, just like with MRI.
- Include several seconds prior to each marker to see the oxy/deoxy levels before and after the stimulus.
- Currently, when working with Ensemble Averaging, it is not possible to average around events based on the Label of the event. So, if Stim-Response was used to automatically obtain Stimulus event markers (which can have labels from 1 to 255), in order to use the Ensemble Averaging function, labels must be changed manually (go in the Event Palette and manually change each of the different labels to a unique type of a marker event). Thus, if there are only up to eight different markers it is best to simply use a different digital channel for each marker and perform averaging around peaks of channels.

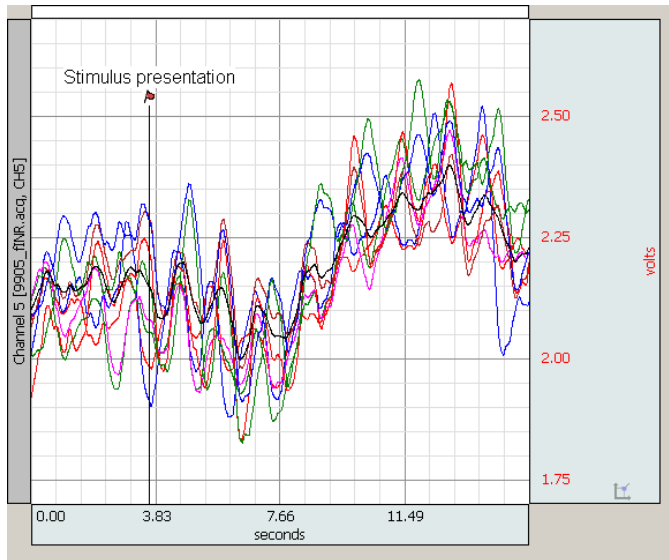


Please highlight the area around the peak to be included in a single averaging pass and click 'Do Average'.





Here is the result of averaging 8 of the oxy channels around one kind of stimulus marker (the Stimulus presentation marker in the screenshot has been added afterwards for illustration purposes – data before and after the marker has been averaged):



10. To obtain an average response for all the channels, use Transform > Expression.

- In the screenshot below, 8 channels are averaged using the following Expression (in T):

$$(CH1+CH2+CH3+CH4+CH5+CH6+CH7+CH8)/8.0$$

