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Turbo-Satori: A novel real-time fNIRS data processing and analysis toolbox

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Introduction: Turbo-Satori is a novel real-time processing and analysis tool for functional near-infrared spectroscopy (fNIRS) data which was acquired using a NIRx recording device [1]. The software is optimized for real-time applications such as neurofeedback and brain computer interface (BCI) applications. It supports online oxy/deoxy concentration value calculations from raw wavelength data and provides advanced in-built incremental statistical analysis (RLS GLM), filtering and trend removal procedures, neurofeedback options as well as network interface solutions to export data to 3rd party applications using the TCP/IP network protocol.

Material, Methods and Results:
The software calculates and shows oxy and deoxygenated haemoglobin concentration values in real-time and provides this values for time course displays and neurofeedback / BCI procedures. Oxy/deoxy concentration values are calculated from the raw wavelength in real-time. A moving average filter can be used to remove physiological confounds like heart-beat fluctuations or high frequency noise. The filter settings can be set in hertz and are internally converted into the moving average filter length. Additionally linear trends can be removed incrementally in raw and oxy/deoxy concentration values. A RLS GLM is calculated incrementally for each data point and the resulting statistics are indicated in the row headers in the channel selection area of the software using received triggers or a predefined protocol containing the different conditions and timings. This allows the user to immediately inspect the channels with the highest statistical significance which are e.g. therefore promising to use for neurofeedback and BCI applications. The contrasts used in the t-test can be changed during and after the experiment to support the channel selection procedure. An important aspect in real-time fNIRS applications is the processing time. In an optimal setup this time should be constant during the whole experiment to be able to present real-time neurofeedback or BCI information. Therefore Turbo-Satori is based on incremental procedures which can be performed in a run time of O(1) for each data point. We measured the processing time using two different datasets, the first datasets using 20 channels and the second using 64 channels. For the first experiment a mean processing time of 2.22 milliseconds (sd=1.47ms) per data point, sampling rate 10,42Hz (~98ms)(20 Channels), was measured. The second dataset performed similar: mean processing time 2,76ms (sd=2.57ms) for each data point, sampling rate 7,81Hz (~128ms) (64 Channels). To fulfill the real-time condition a processing time below the sampling rate is required.

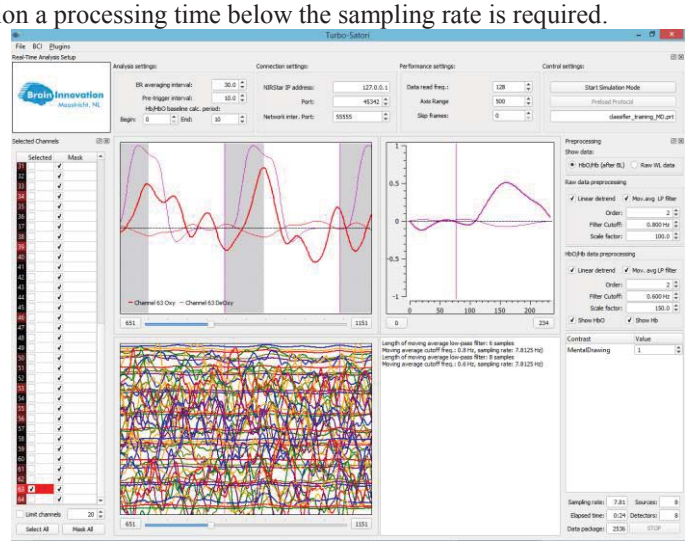

Figure 1. *User interface of Turbo-Satori. The user is able to inspect channels in detail and combine them in one view. All preprocessing parameters can be adjusted in on-line and are accessable during data acquisation. A log window shows current information.*

Discussion: Different filter types need to be tested and applied in real-time fNIRS conditions to evaluate the improvement in filtering quality and allow more filtering options. This would allow to correct for stronger artefacts and signal fluctuations in real-time.
Significance: A novel fNIRS toolbox was introduced performing different preprocessing and analysis procedures in real-time with a processing time for each data point of O(1).
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References: [1] NIRx Medical Technologies, LLC