Webinar Q&A Report:

fNIRS and Brain-Computer Interfaces for Communication

Q: I have a question regarding the 10 second delay between the different choices for the multiple choice BCI Dr. Sorger developed. Is 10 seconds too short of a delay? What happens if someone has an inherently delayed hemodynamic response?

Usually the hemodynamic response has roughly a 3 to 6 second delay. 10 seconds should be enough to house the majority of any temporal delay in the hemodynamic response. This can be individualized for patients with shorter or longer hemodynamic response times by use of "pre-sessions". Pre-sessions would provide the ability to fine tune different on a more individualized basis, including the encoding time.

Q: Can you send a link for the analysis software for fNIRS BCI data?

The software that was used in the webinar was TurboSatori. You can find it here.

Q: For Dr. Sorger: Temporal variability usually depends on so many different factors: like other cognitive background processes, etc. How can you know exactly that the second delay of the peak (2nd color decision, for example), it is the actual response of the representative color stimuli, and it's not an effect of the previous stimuli but delayed? (mainly based on that long interval of 10s)?

As mentioned earlier, classifiers are fine tuned for each subject during pre-sessions. If a subject shows a delayed hemodynamic response, this can be identified and characterized during offline analysis. The hemodynamic response function that best fits their data will be used for online encoding of that subject. Of course, there can be many other ongoing cognitive processes which can mask the response voluntarily evoked by the subject and we can never know exactly what is the origin and the cause of the signal we are encoding. The best we can do is optimize the classifiers as much as possible during individual pre-sessions to make them as robust as possible to eventual interferences.

Q: Imposing an additional 10s for each decision will involve a delayed final response of the BCI. How can this be avoided and reduced when aiming for real time BCIs?

This question was partly addressed by Dr. Sorger during the webinar. It is clear that the multiple choice approach based on time encoding adds a delay additional to the intrinsic delay of hemodynamic response and there is no doubt that this presents a limit to "real time" BCIs. However, if such a BCI works, the disadvantage of the time delay for the subject is insignificant compared to the benefit of successfully being able to communicate.

Q: In the results, only the first decision was classified beyond the chance level. What about the other decisions? Why they were not decoded? Does this have to do with the temporal variability?

We are describing here our interpretation of the results illustrated by Dr. Sorger, we will kindly ask her to confirm. It is not the case here that the accuracies of options B, C or D to be correct are significantly lower than the accuracy of option A. We imagine that the classifier outputs for each of the four options A,B,C,D, their probability of being the correct one, starting from the most probable one. What Dr. Sorger mentioned in slide 47 as "1st decoder option being correct" does not refer to option A, but rather to the option identified by the decoder as being most probably the correct one. As you can see, in most cases, the 1st option identified by the decoder is the correct one (it is not clear nor relevant if that was option A, B, C, D).

Q: How did GLM help to select the best channel for classification accuracies?

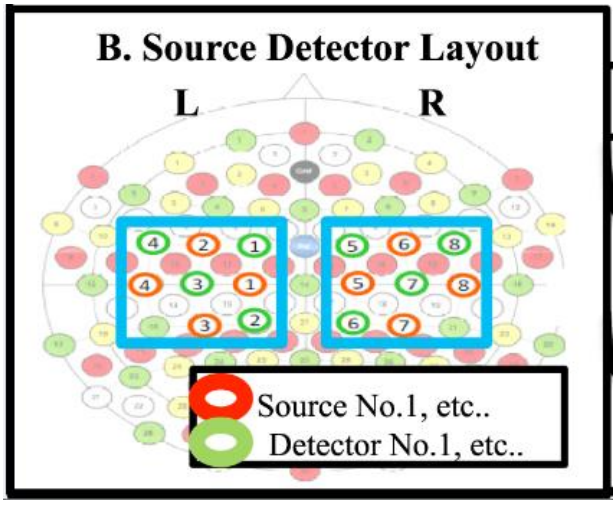
The GLM was calculated on each channel. Once calculated, the channel best fitting the model was then used for deriving the encoded answer.

Q: How did Dr. Sorger determine the location of the sources and detectors while setting up her experiment?

The goals of the optode placement was to make sure the left sensorimotor cortex was fully covered. Since all subjects were right-handed, the right sensorimotor cortex was of no interest. Generally, there are several ways of defining the optimal placement of the optodes based on an identified ROI. NIRS systems manufacturers may provide guidelines based on their headgear characteristics. NIRx, for example, provides templates for different cortical regions for their caps. There are also several tools that may be helpful: the toolbox implemented by the group of Dr. Dan can be very helpful to identify the anatomical label of the target region based on the MNI coordinates of sources and detectors. It is also possible to digitize the positions of sources and detectors and overlay them to anatomical scans, in order to have a more accurate understanding on where exactly the optodes are. Dr. Sorger for example, is acquiring anatomical scans on subjects already wearing fNIRS caps, in which the positions of sources and detectors are marked by contrast agents.

Q: During Dr. Chaudhary's experiment for which the video was shown, where were the optodes placed?

The optodes (both sources and detectors) were placed on both hemispheres of the frontocentral region of the scalp (see Figure to right).



Q: Which brain areas was Dr. Chaudhary focusing on during the measurement?

Cortical oxygenation in the region of the cerebral cortex underlying the frontocentral region of the scalp (see Figure to right) was measured.

Q: For Dr. Chaudhary: What if the patient is delusional (i.e. they might believe Berlin is the capital of Spain), how to work around this?

Strictly speaking, it is not possible to work around delusion. However, by repeatedly asking overlearned ('Berlin is the capital of Spain') together with personal questions ('your husband's name is Joachim'), and by checking the consistency, one may assume with certain confidence that patients are not delusional.

Q: Why do you think the response for "NO" for some patients is going negative?

The physiological background of why YES and NO responses result in these hemodynamic responses has not been given by the group of Dr. Chaudhary. As long as these responses are consistent and reproducible, the physiological origin of the response is not relevant for the BCI. One explanation could be that patients may have different approaches as to providing their 'mental answer' to the questions. Alternatively, individual differences in brain plasticity in the motor network (resulting from disease progression of ALS patients) may play a role.

Q: Does the type of experiment or stimulation play any role in the performance of the classification?

Yes, the more complex the stimulation or experiment the more complex the hemodynamic responses. If questions become too complicated, say requires more levels of thought or high involvement of executive functions, classification becomes more difficult.

Q: During Dr. Chaudhary's experiments, what exactly was the task the patient had to do as "yes" or "no"? Was it just to think of the answer?

Yes, the patient had to repetitively think of the answer, i.e. "ja, ja, ja..." (German for "yes") or "nein, nein, nein..." (German for "no") over the 15 second time period for each question.

Q: How efficiently can one attempt connectivity analysis with fNIRS? Is there any software currently available to accomplish this?

fNIRS can bring connectivity studies to a new level of applications with the hyperscanning modality, which enables both online feedback as well as offline analysis regarding within- and between-subjects connectivity. Moreover, the fast sampling rate of fNIRS for hemodynamic states allows for a quick update rate of connectivity feedback, representing a higher subject engagement to the task. A selection of papers performing connectivity analyses can be found here. The number of toolboxes and or applications that allow for connectivity analysis on fNIRS is still limited. The new toolbox developed by Dr. Ted Huppert seems to have this feature as well. Another toolbox that seems to offer a similar feature is this.

Q: What is your preferred filter/frequency used when filtering data?

The most common frequency filter is a bandpass filter, with values somewhere between 0.01 and 1 Hz. The lower limit removes most electronic noise while the upper limit removes most physiologic noise. Depending on your experiment or environment these numbers may change.

Q: Dr. Sorger mentioned that sampling frequency in fNIRS can be up to 20Hz ... could you comment on the tradeoff between number of channels and sampling frequency?

When operating in time multiplexing mode, the total sampling frequency decreases with the number of sources. NIRx systems employ a sampling rate of 62.5 Hz. This is divided by the total number of "steps". Steps simply mean the number of individual light signals sent. Typically, this would equal the number of sources, but can be decreased by firing distant sources simultaneously.

Q: I would like to know more about fNIRS qualitative signal. How can we know which kind of artifact are we dealing? Is there any special program for data treatment and remove artifact? For instance, similar to ICA for EEG.

Yes, there is an abundance of free software to deal with your fNIRS data. In house NIRx offers nirsLAB, but we do recommend several out of house options as well. Most notably Ted Huppert's NIRS Toolbox, or for those with less programming experience there is also a more GUI based option called Homer2 out of Harvard. You can find NIRS Toolbox here and Homer2 here.

Q: Have you experimented with white laser light instead of infrared to achieve higher tissue penetration and better localization?

fNIRS more readily focuses on near-infrared light due to its ability to penetrate the skull and interact with hemoglobin, while lacking interaction with water. Most of the light convolved in white light would merely be disregarded upon reaching the scalp and skull, while most light in the infrared spectrum and beyond would interact too readily with water. If the question was intended to address the choice of LED versus LASER light (while both in the infrared spectrum), it is important mentioning that while laser light is highly collimated, it does not guarantee better penetration nor better localization. This is due to the scattering properties of the underlying biological tissues.

Q: I would appreciate some details on the preprocessing of the NIRS signal: choosing between the different NIRS signals (oxy, deoxy, their mean …), bandpass filtering applied - how do you choose their values? Are there any gold-standards? Projection out any reference signals (like we usually do with head movements and BOLD response in the ventricles in fMRI analysis)?

A lot of information related to preprocessing data, inspecting the various measures (e.g. oxy and deoxy) and applying filters can be found in the nirsLAB manual.

Q: It is mentioned in some of the research papers that the mathematical adjustments were made while carrying out measurements for the sake of getting most accurate and precise measurements. What are those adjustments?

Most likely, these mathematical adjustments consist of artifact removal and bandpass filtering, although more specific adjustments may have been made too. There are several different processing steps applied to the raw data, before these are converted into hemoglobin concentrations. Generally, each study reports in detail the exact algorithms applied.

Q: Is it possible to use an fNIRS device for other applications (i.e. VR, gaming, etc.)?

Definitely, BCI is just one of the many applications. Under http://nirx.net/publications you may find an extensive list of published studies, categorized by application. There are many studies already published in both fields you mentioned, gaming and VR. In hyperscanning mode it also possible for example to study the interaction of multiple players during a game / video game.

Q: How about brain-to-brain (BIB) interface? Do you think that it can work in the future?

At NIRx we currently support a variety of tandem setups to record two individuals simultaneously. Currently I have not seen any work done with fNIRS and BIB interfaces, but would love to see this being worked on in the future. There will be some difficult troubleshooting involving the inherent hemodynamic response delay, but I see this as being a logical step in the not so distant future.

Q: Have there been any studies using chronic pain and fNIRS?

Chronic pain has been the focus of study on several fNIRS studies. Many of these studies investigate at a known treatment modality by viewing the hemodynamic responses that the treatment evokes. For example, Vrana et al. (2016) investigate sensorimotor processing of painful pressure stimulation by using fNIRS to measure cortical hemodynamics and oxygenation.

Q: I would like to use this technology to investigate the behaviour of these patients (like ALS), particularly the helplessness feeling present in this kind of patient... Can you advise me on how to use fNIRS in this case, particularly regarding receptor localization?

Many interesting studies have been published, that investigated emotional states using fNIRS. For example, have a look here. As mentioned earlier, there are several ways of building the optimal sensor placement based on a defined region of interest. Please feel free to contact us any time at support@nirx.net for more practical examples.

Q: Are there cases in which SVM perform better than LDA or vice versa?"

Which classifier should be used (e.g. SVM or LDA) entirely depends on the dataset, underlying assumptions, and the specific aim of the analysis. In general, it could be said that SVM focuses mostly on data points (or cases) that are difficult to classify, whereas LDA focuses on all data points. In short, LDA is generative whereas SVM is discriminative.

Q: Can fNIRS be used with neonates?

fNIRS can be used on neonates! In fact, we have neonate specific hardware to make neonate studies as comfortable as possible and there are many papers published using fNIRS on neonates. As mentioned in many studies (http://nirx.net/publications#development and http://nirx.net/publications#infants), fNIRS has the advantage of being very well tolerated by infants and of enabling very easy and quick setup.

Q: Can machine learning methods be used for fNIRS signals like in EEG signals?

Yes! The machine learning methods can be used for fNIRS signals.

Q: Can we do interaction based emotion experiment where participants are interacting with each other and we are recording the signal at the same time. Would it be feasible study wise and cost wise?

Yes, definitely. For example, NIRx fNIRS systems operate also in hyperscanning mode, allowing for simultaneous recording of two or more subjects. This feature has been particularly exploited when studying emotions.

Q: Can you also mention which BCI are mainly used with adults and which with children and infants?

There is no clear answer to this as which BCI will be used depends on several factors, such as the purpose of the study and the brain region of interest. Advantages and disadvantages of specific BCIs are specified in the presentation of Dr. Sorger, on slide 11. When studying children, one of the most important factors to consider is the degree of tolerance of the used technology. For example, fMRI may not be suited in this case.

Q: I've understood that the EEG is not a good option for BCI in this group of patients while the fNIRS is. What can we take away from this to improve our comprehension of the completely locked-in state? In other words, what characteristic of the completely locked in state would cause the BOLD signal to be a better option?

Indeed, in the study Dr. Chaudhary presented, correct classification of "yes" and "no" answers given mentally through fNIRS exceeded classification of EEG oscillations from 0–30 Hz. Thus, fNIRS seems to provide better classification of patients' answers compared to oscillatory EEG responses. However, stating that fNIRS is superior over EEG–BCI in this particular study needs a word of caution. This is best expressed in the Discussion section of the paper of Dr. Chaudhary and colleagues, which can be found here.

Q: We are using near infrared light therapy to help alleviate cognitive impairment. Would you say that the positive effects of this type of intervention is best captured by a neuroimaging modality such as fNIRS (given the consistency of near infrared use in the intervention and fNIRS)?

To correctly answer the question, we would need to know the full technical details of the NIR light therapy system. Depending on the light properties, the spectra, the type of light sources, the times of emissions and the placement of the system relative to the head, the therapy system may or may not interfere with the fNIRS measurements.

Q: What is the biggest limitation/challenge for using an fNIRS device?

The most notable limitation with fNIRS is the depth of tissue that fNIRS is able to image. Activity in deep brain regions cannot be measured using fNIRS

Q: Will the fNIRS-EEG combined device be a new trend of fNIRS device?

This may indeed be the case, it is in fact something that is of great interest.

Q: Can you suggest some good papers with BCI for us to refer to?

We have many we would suggest on our website under publications. Click here for the link.

Q: Role of initial dip in BCI

This entirely depends on the paradigm that is used. For example, in the study by Dr. Chaudhary, the relative change in oxygenated hemoglobin during the entire interstimuli interval is used to classify "true/yes" and "false/no" answers. This interval includes the initial dip in the hemodynamic response. Alternatively, other BCI paradigms only focus on the hemodynamic peak, and thus ignore the initial dip of the hemodynamic response. Using only the initial dip of the hemodynamic response in BCI may be unreliable.

Q: How difficult is to setup fNIRS over an EEG cap to perform multi-modality recording?

We would suggest implementing the EEG and fNIRS into the same cap. It would require what we refer to as "grommets" specific to both fNIRS and EEG at the desired locations. NIRx offers a range of fNIRS/EEG ready to go caps. Once the cap is on, the typical EEG set up is required, followed by the typical fNIRS set up. Keep in mind the EEG set up may require gel, whereas the fNIRS setup will not.

Q: What is the fundamental difference between fNIRS based BCI and EEG Based BCI?

This question can be translated back to what is the fundamental difference between fNIRS and EEG. We are measuring two different signals, with intrinsically different characteristics. When it comes down to BCI, the most important question is: how accurate is my classifier? In some cases, EEG may be better, in some cases fNIRS. It does not have to be an exclusive choice: many studies have published hybrid BCIs, which combine both fNIRS and EEG either to increase accuracy (by creating hybrid classifiers) or by increasing the number of commands (some to be classified through fNIRS, some through EEG). The most important difference between EEG and fNIRS based BCIs is the temporal resolution: due to the hemodynamic delay, fNIRS can be seen as a slow BCI. However, if the accuracy of classification achieved with fNIRS is higher than with other faster technologies, then the temporal resolution may not matter at all.

Q: Which part of FNIRS better than EEG?

Both techniques have their advantages and disadvantages: fNIRS tends to have a better Signal to Noise Ratio (SNR) than EEG as well as better spatial resolution.

If you have additional questions for NIRx regarding content from this webinar or wish to receive additional information about solutions for fNIRS research, please contact them by email:

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