Baseline calculation and considerations in fNIRS

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For EEG or NIRS data analysis, there is a baseline problem which confuses many students and teachers. Why do we need to use baselines and how to use them correctly?

In this article, we mainly discuss the baseline problem of NIRS. The baseline in EEG data analysis will be elaborated further in the series of our articles regarding EEG data analysis.

— from NIRX article

At present, most of the light source emission methods used in NIRS are continuous wavelength (CW). It is impossible to sample absolute path signals completely. Therefore the changes of blood oxygen concentration relative to another time point are always measured and evaluated. For example, to study the change of oxygenation in response to stimulus is actually to measure the relative response between the short time before the stimulus and during the stimulus. The time before the stimulus is usually called the baseline.

What is the baseline?

Some researchers who start to learn how to use NIRS technology don't know the meaning of measurement results and the baseline. We would like to discuss the origin of baseline first.

The most commonly used NIRS is CW-NIRS, which is based on the modified Beer-Lambert law. By

a continuous emission source, near-infrared light enters the brain tissue and it scatters (changes its direction) and be absorbed. Such change of optical properties is used to study brain activity. Both scattering and absorption are the reasons why CW-NIRS can measure brain activity.

When we put our finger on the front end of the red laser generator, the penetration of red light in the finger is clearly visible. You will see that the entire finger penetrates the red light through the light. Light scattering in the tissue or part of the light being scattered and absorbed by the finger is the reason why CW-NIRS could provide relative measurement. The light is absorbed by the internal hemoglobin and then penetrates. However, by penetrating the red light on the finger, we don't know what changes have occurred inside the finger. As in this test, we did not detect the red light from the red laser penetrating the finger by detector.

Assuming that scattering and absorption in all directions of the tissue are constant, when we measure the change in the near-infrared light through the detector, then the path of the near-infrared light from the source to the receiver will definitely change.

At present, the study of the brain by near-infrared light utilizes the sensitivity of hemoglobin to near-infrared light in brain tissue, near infrared light into brain tissue that most of the changes are caused by the absorption of hemoglobin in cerebral cortex tissue. Of course, near infrared light can also be absorbed or scattered by other tissues (such as fat, hair, skin, skull, hydrocephalus and other irrelevant tissues), however, it is also inevitable. Therefore, we assume that the absorption is constant during the measurement and that all changes in the near-infrared light detected are caused by the brain tissue hemoglobin absorption. Since hemoglobin has changed in brain tissue, there must be a relative "initial state". For NIRS equipment with continuous wavelength, a detector receives the change of near infrared light, and then calculates the change of hemoglobin concentration according to Mod Beer-Lambert law. So, for this process of change, we think it is related to the value of the "starting state"

CW-NIRS can only be used to measure the relative change of blood oxygen concentration, so it can not provide the "initial state" concentration value. However, it can provide baseline changes caused by the state of any task or study (e.g., increased activity in a part of the brain or the start of a task state). The unit of concentration is usually measured in terms of mmol per liter (mmol/liter or mM). It may be positive, which means activation from task or research state. It could also be negative, which means reduction or inhibition of relative concentration of self-task or research state.

How to use the baseline?

It may be more difficult to get a better baseline than to get it under theoretical conditions. We can set any point in the data as the starting value (by subtracting the starting value from all data points), or at a specific time (for example, the initial resting state is 30s, 1 minute can be collected if conditions permit), the baseline segment is obtained in the resting state, and the average value of the segment is calculated and then subtracted from all the data points collected.

Operations which are not allowed

Do not compare baseline averages between groups, because the average of each group is arbitrary and should be set to zero when it is possible. In addition, there should be no continuous stimulation between stimulation tasks, and time should be allowed to restore blood flow to baseline level.

Summary

In this article, the importance of using the baseline is explained theoretically. The baseline correction is also needed before the stimulus in the EEG data. In short, when we are using the near-infrared technology to study the brain, the baseline setting should be as smooth as possible, which is also one of the basis for judging the experimental design.