Part I: EEG & tDCS

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neuroConn's full-band EEG system NEURO PRAX® TMS/tES measures EEG-signals and Evoked Potentials during:

- TMS (transcranial magnetic stimulation)
- tES (transcranial electric stimulation)
- tDCS (transcranial direct current stimulation)
- tACS (transcranial alternating current stimulation)
- tRNS (transcranial random noise current stimulation).

The special NEURO PRAX® TMS/tES hard- and software offers:

- short recovery time 3-5 ms after TMS pulse
- high dynamic input range and resolution
- online artefact correction software for TMS and tACS artefacts
- full-band recording (0-1200 Hz) of EEG, EMG, ECG, EOG, ...
- online data interface to Brainsight® TMS navigation software
- export functions for analysis software (BESA, EMSE, ...)
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The application notes cover recommendations for the use of the NEURO PRAX® TMS/tES system in combination with:

- EEG and tDCS (part I)
- EEG and tACS (part II)
- EEG and TMS (part III)

The application notes show examples for measurement setups, recommended ways for mounting the EEG electrodes, electrode setups and recorded data.

Additionally to these application notes, read the safety instructions in the manuals of your NEURO PRAX® TMS/tES device, your DC-STIMULATOR (especially limits of applied currents, current densities, duration and electrode application) and in the manual of your TMS device.

Due to the battery driven amplifier and stimulator as well as medical power supply powered NEURO PRAX® there is highest possible safety for research.
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Measurement Setup

The Optical Trigger Module (optional hardware) converts electrical trigger signal from TTL-BNC, parallel port or from USB port to optical trigger events for the NEURO PRAX® amplifier.

Twist the electrode cables to form only one cable harness. This reduces the power line interferences (50/60 Hz).

Increase the distance between NEURO PRAX® amplifier and power line devices (e.g. NEURO PRAX® system or other electrical devices). This reduces the power line interferences (50/60 Hz).

Place the DC-STIMULATOR PLUS and the NEURO PRAX® amplifier behind the patient on a non-metallic table. Disconnect all charging devices. This reduces the power line interferences (50/60 Hz).

Twist the electrode cables to form only one cable harness. This reduces the power line interferences (50/60 Hz).

The Optical Trigger Module (optional hardware) converts electrical trigger signal from TTL-BNC, parallel port or from USB port to optical trigger events for the NEURO PRAX® amplifier.

A: Anode
C: Cathode
Ti: Trigger Input (optional)
To: Trigger Output (optional)
Ri: Remote Input (optional)
So: Signal Out (optional)
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Electrode Mounting

Materials:

- EEG caps of different sizes with ring adapters and chin strap (1)
- Ag/AgCl ring electrodes (2)
- isopropyl alcohol (3)
- double-sided adhesive tapes for EOG electrodes (4)
- cotton swaps (5)
- stimulator cables (6)
- stimulator electrodes with Ten20 paste (7)
- 2x12 ml syringe with AbralytHiCl gel (8)
- waterproof pen (9)
Choose the right cap size for your patient! Pay attention for correct fit of the cap! This is important for good EEG signals.

- cap size too small
- incorrect fit, unstable or no contact
- correct cap size, correct fit
Put the EEG cap on the head of the patient. Adjust the cap position to match the Cz position (vertex). This is the cross of the line from Nasion to Inion with the line between the pre-auricular points. The length from Nasion to Cz and from Inion to Cz should be equal. Check the correct positions of Fp1, Fp2, O1 and O2. Mark the positions of the stimulation electrodes on the skin with a waterproof pen. Remove the cap.

Apply Ten20 electrode paste evenly at the stimulation electrodes. Create a plait at the stimulation position. Take a cotton swap and clean the skin around the plait with isopropyl alcohol. Move the hair through the whole of the stimulation electrode and press the stimulation electrode on the head.
circular electrodes with hole ($\Phi_i = 3$ cm; $\Phi = 7.5$ cm; $A = 37.1$ cm$^2$):

alternative: rectangular electrodes (5x7 cm; $A = 35$ cm$^2$):
Connect the stimulation electrodes with the DC-STIMULATOR and check the impedance.

**A low impedance between the stimulation electrodes is most important for good tDCS-EEG recordings. The impedance should be lower or equal to 5 kΩ.**

**DC-STIMULATOR S/N < 1000:**
Use a tDCS stimulation (single mode) with 0 μA to check the impedance. The initial value at the beginning shows the correct impedance.

**DC-STIMULATOR S/N ≥ 1000:**
Press the lower left button, hold this button. Now press the upper right button to check the impedance.
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Put the EEG cap on the head of the patient. Check the correct positions of Fp1, Fp2, O1 and O2.

Place the GND electrode (EEG amplifier) in the middle of the stimulation electrodes.

EEG-Signal close to the GND electrode have smaller tDCS artefacts compared to EEG position far away from GND.

We recommend to use the right mastoid for the REFERENCE EEG electrode. We don't recommend ear lobe positions.
Preparation of electrode-to-skin contact for EEG/EOG electrodes:
We recommend to perform each step for ALL electrodes before you go to the next step.

STEP 1: Click off the electrode from the ring adapter.
STEP 2: Move the hair away from the centre to the outer side (picture 2). Skin should be clearly visible (picture 3).
STEP 3: Fill-up a small amount of Abralyt HiCl gel. Rubber gently. The skin should be visible all the times. Don't twist the hair.
STEP 4: Click in the electrode into the ring adapter. Skin should be always be visible.
STEP 5: Fill-up with Abralyt HiCl gel.

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Correct placement of amplifier and stimulator on a non-metallic table behind the patient.

Strain-relief for EEG cables on the right shoulder.

EOG electrodes with double-sided adhesive tape and ring adapters.
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Electrode Setups

EEG-19 / EEG-27 / EEG-New:
for tDCS & EEG recording

ERP-19 / ERP-27 / ERP-New:
recording and analysis of event related potentials

TES-EEG-19 / tES-EEG-27 / tES-EEG-New:
for tACS & EEG with artefact correction

for TMS-EEG recording with artefact correction, analysis of TMS event related potentials and transfer to Brainsight®

EMG-15 / EMG-New / EMG-15-BS / EMG-New-BS
for TMS-EMG recording with artefact correction and transfer to Brainsight®

The “New” suffix indicates that the user can drop channels (not storable setup).
Suffix “-19” for 19-channel recordings, suffix “-27” for 27-channel recordings.

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Check the impedances of all EEG electrodes and correct the electrode – skin – contact if necessary.

Ready for recording and stimulation!
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Examples

EEG recording before tDCS
eyes closed condition with α-waves
The exact time stamp of the stimulation start can only be recorded with the Signal Out for NEURO PRAX® hardware extension.
EEG & tDCS 1000 µA

EOG blink artefacts

eyes closed condition with α-waves

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EEG & tDCS

1000 µA

Fade-Out

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How can the user check, if the NEURO PRAX\textsuperscript{®} system records the EEG correctly during tDCS?

- It shall be for a qualified physician to evaluate the EEG signals.
- A qualified physician can identify $\alpha$-waves in eyes-closed condition during the tDCS stimulation. They should be clearly visible in the occipital channels.
- Eye-blink and movement artefacts should be visible mainly in the frontopolar channels during tDCS.
- Use the rubber band to measure the fade-in time and fade-out time in the EEG signals. Compare this time to the settings of the DC-STIMULATOR. It is a proper sign that the amplifier did not run into saturation if stimulator settings and measured time are equal.
Please note: stimulating with 3000 μA should show the capability of our NEURO PRAX® DC-EEG amplifier to cope with high potentials generated by this high stimulation current. There is currently no literature published, showing tDSC with this high current.
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