The Problem With Concurrent EEG and tDCS

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Disclosure:

The City University in New York has patents on brain stimulation and EEG with Bikson as inventor. Bikson is founder and has shares in Soterix Medical which produces tDCS and HD-tDCS. Bikson serves on the scientific advisory board of Boston Scientific Inc.

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3 problems with concurrent EEG and tDCS (tES / tACS)

1. **Inherent Stimulator Artifacts.** Real stimulation and EEG equipment limitations: limitations much be acknowledged and quantified.
   - Range from minimal to severe in a device specific manner. Cannot be dismissed.

2. **Inherent Physiologic Artifacts.** Interactions between body and stimulation that are detected by the EEG.
   - Are independent of equipment used. Cannot be dismissed.

3. **Non-inherent Artifacts.** Controllable artifacts that result non-ideal setup or experimental conditions.
   - Can be accounted for in training and monitoring, not ignored.

Not acknowledging these issues raises concerns of reproducibility.
tDCS generates large "DC" potentials on the scalp, that are detected by EEG
tDCS generates large "DC" potentials on the scalp.
tDCS generates large “DC” potentials on the scalp, that are detected by EEG

- Artifacts specific to electrode montage (size / position) and subject (head anatomy), linear with polarity / intensity
- [minor] Variation over time and within subject across tests
- [general] Topography can be predicted by current flow models
Predict DC potentials on the scalp using current models
Predict DC potentials on the scalp using current models
Assume static tissue conductivities

Datta et al. *Brain Stimulation* 2009 Gyri-precise model of tDCS.

Huang et al. *eLIFE* 2009 Measure of electric field in human brain.
There is an evident (if you look) broad-band artifacts in the EEG during EEG
4 tDCS devices, including Analog Device

Comparable topography, HD M1-SO montage

[special] Post-stimulation offset
4 tDCS devices

Site specific broad-band

Worse with Activadose Device, preset even with Analog Device
There is an evident (if you look) cardiac artifact during concurrent tDCS and EEG.
Model predicts cardiac artifact

Assume 0.1% change in skin conductivity (ballistocardiogram)

Explains montage/ intensity/ polarity specific cardiac artifact
Evident distortion of blink (ocular) artifact
Model predicts cardiac artifact

Model blink as skin over eye

Explanes montage/intensity/polarity specific additive blink artifact
Likely a muscle (myogenic) artifact during tDCS in EEG
Model predicts myogenic artifact

Assume 1% change in select muscle conductivity

Montage/ intensity / polarity specific
Shared features of Inherent Physiologic Artifacts in EEG + tDCS

- Each be understood as incremental change in the large DC scalp potential – substantial compared to EEG

- For this reason, they are all inherent (present in any equipment) and are dose (montage, polarity) current, specific

- Topography influence by dose and physiology. Temporal features by physiology.

Typical ”control” experiment may fail. Artifacts change with dose and are localized near stimulation sites.

To the extent the DC potential drifts, they are not stationary.
• Not acknowledging these issues raises concerns of reproducibility.
Final thoughts

• Issues exist with other tES waveform but distinct manifestations, and expected in MEG

• Verify minimal post-tDCS artifacts effects plus scalp conductivity changes (?)

• EEG systems that can capture the scalp artifact (wide range) allow this information to be used in artifact correction

• Possible to use the DC (e.g. verify current flow) and physiologic artifact artifact (e.g. heart rate monitor)

Noury et al. 2016
Physiological processes non-linearly effect EEG

Datta et al. J. Neural Engr. 2013
Validation using scalp potentials.

Charvet et al. J. Frontiers 2015
Remote supervised tDCS
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