REPLAY OF ENDOGENOUS SLEEP RHYTHMS TO PRODUCE SLEEPINESS

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Background and Aim

There is a long history of attempting to induce sleep-like state through electro-stimulation techniques. Prior studies used synthetic (simplified) pattern of transcranial electrical stimulation (tES), such as sinusoidal stimulation (tACS) in order to replicate an endogenous frequency of neural sleep signatures (e.g., delta activity) or as an arbitrary waveform (e.g. pulse trains, tDCS).

Our general aim is to replay the endogenous sleep rhythms to promote sleepiness and enhance the spontaneous wakefulness-sleep transition. Our hypothesis is that a complex waveform derived from endogenous sleep activity is more effective than a synthetic waveform in supporting the transition to sleepiness.

We designed a transcranial Endogenous Sleep-Derived (tESD) waveform. Objective (neuro-physiological) and subjective (behavioral) measures of sleepiness were collected from subjects in a relaxed state. The effects of tESD were compared versus 10Hz tACS and a no-stimulation conditions.

Materials and Methods

Study Design
- Ongoing cross-over study.
- Subjects: 10 healthy students of the City College of New York, CUNY.
- Inclusion criteria:
  - Medication-free
  - No sleep disturbances
  - No contraindication to tES
- Study Arms:
  a) HD-tESD
  b) HD-tACS (10 Hz)
  c) Resting state (no stimulation)
- Dose: Max 0.5 mA, bipolar, for 11 mins
- Montage: HD-Bifrontal (AF7, AF8)
- Sessions sequence was counterbalanced across subjects.
- Participants were blinded to the condition.
- At least 1 night between sessions. Each subject will be tested at the same hour to avoid circadian rhythm-related alternations.

Intervention / Apparatus
- tDCS devices: 1) X1 EES (Soterix Medical Inc.), 2) X1 Current Controlled Current Source (Custom made)
- Stimulating Electrodes:
  - HD Ag/AgCl sintered ring electrodes (Soterix Medical Inc.)
  - EEG/CoP: Engo Sports / 32-channel Waveguard with integrated HD holders (ANT-Neuro)

Data / Analysis
- EEG: Sampled at 2 Hz, online referenced to CPz
- Analytic: Done using Matlab 2018b, EEGLAB
- Finite Element Models: ScaniP, COMSOL

Transcranial Endogenous Sleep-Derived (tESD) Stimulation Waveform

EEG processing

• Sleep segment selected
• Filter EEG data (0.35-45 Hz)
• 6 frontal electrodes
• Apply amplitude modulation
• Apply compression curve
• Scale waveform 0.5V/0.5mA

EEG Sleep recording-Source

Exemplary Results

EEG Time-Frequency Distribution

No stimulation

tESD stimulation

10 Hz tACS

Heart Rate Over Time

No stimulation

tESD stimulation

10 Hz tACS

Respiration

No stimulation

tESD stimulation

10 Hz tACS

PVT Outcomes

No stimulation

tESD stimulation

10 Hz tACS

Summary

PVT

No stimulation

tESD stimulation

10 Hz tACS

Accuracy (%)

100

97.5

100

97.5

100

85

mean RTs (ms)

283.1

235.2 +0.000

291.5

227.9 0.544

228.8

299.8 0.598

SD RTs (ms)

44.7

57.7

57.3

67.6

46.3

54.1

tESD reaps both the endogenous neuronal signature of sleep.

tESD is tolerated and blinding effective.

Neuropsychiological (EEG, heart rate, respiration) and behavioral (simple reaction time-PVT) data indicate a deeper state of relaxation or wakefulness-sleep transition.

Questionnaires (10 min)

PVT (3 min)

EO-EEG (3 min)

EC-EEG (3 min)

Intervention Arm (10 min)

EEC-EEG (3 min)

EO-EEG (3 min)

PVT (3 min)

Questionnaires (10 min)

Subject Set-up

Psychomotor vigilance task (PVT)

Trial 50

ITI [1.5] sec

Trial 1

Study Layout

Questionnaires (10 min)

PVT (3 min)

EO-EEG (3 min)

EC-EEG (3 min)

Intervention Arm (10 min)

EEC-EEG (3 min)

EO-EEG (3 min)

PVT (3 min)

Questionnaires (10 min)