Interactions with health: Stress, sleep; Utility of biofeedback

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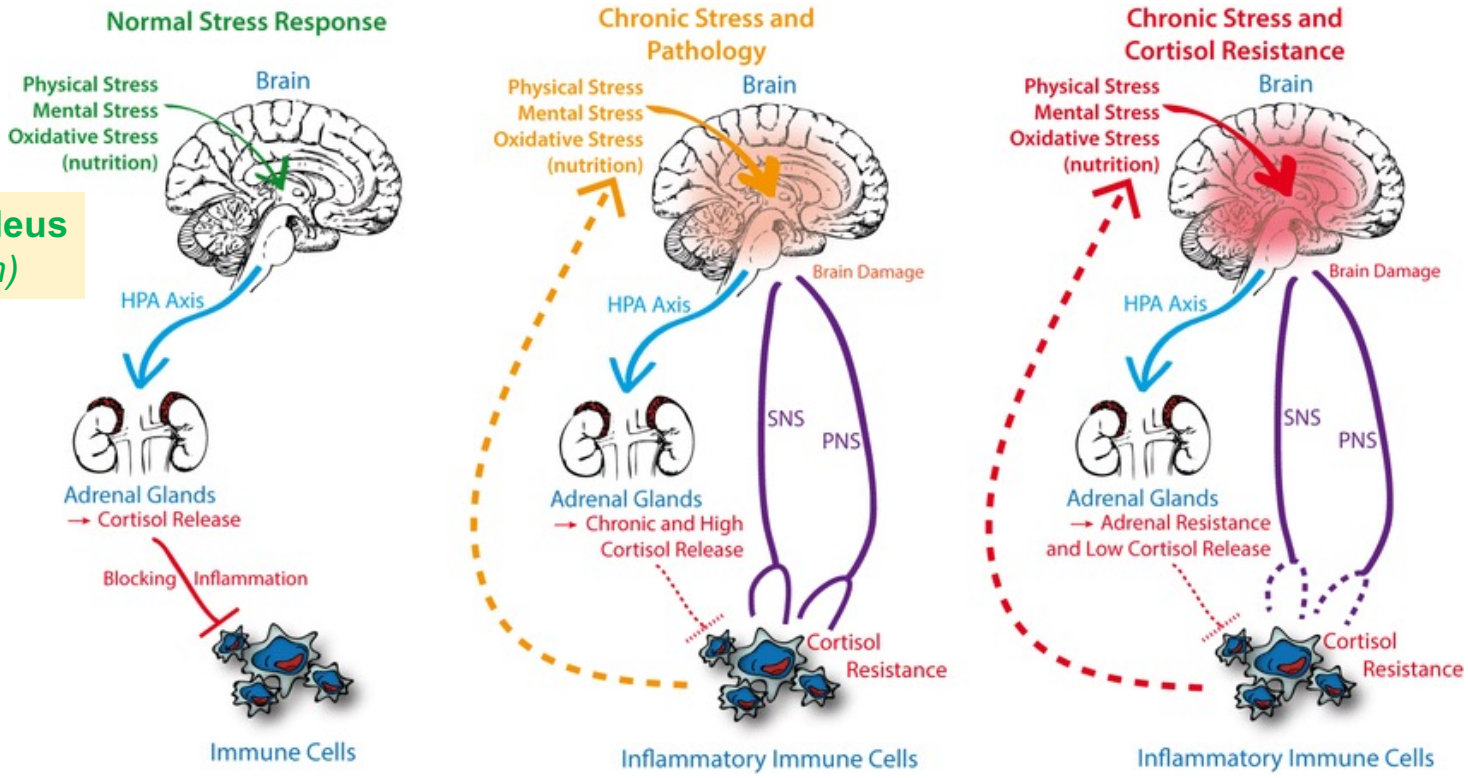
University of South Carolina

PY 888 – Affective (Cognitive) Neuroscience
Spring 2023

Areas of health that may impact affect, emotion, and mood?

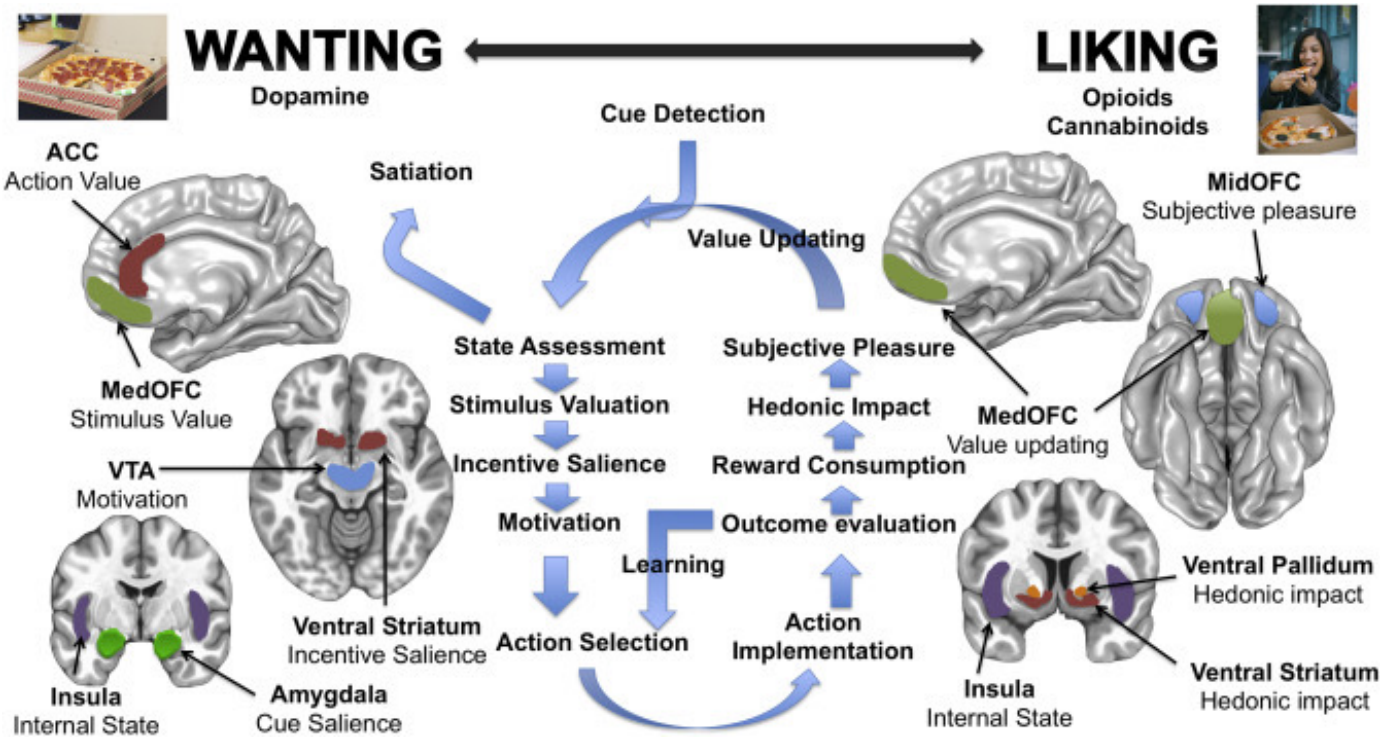
Role of stress

Locus coeruleus
(brain stem)



Fonzo, 2018

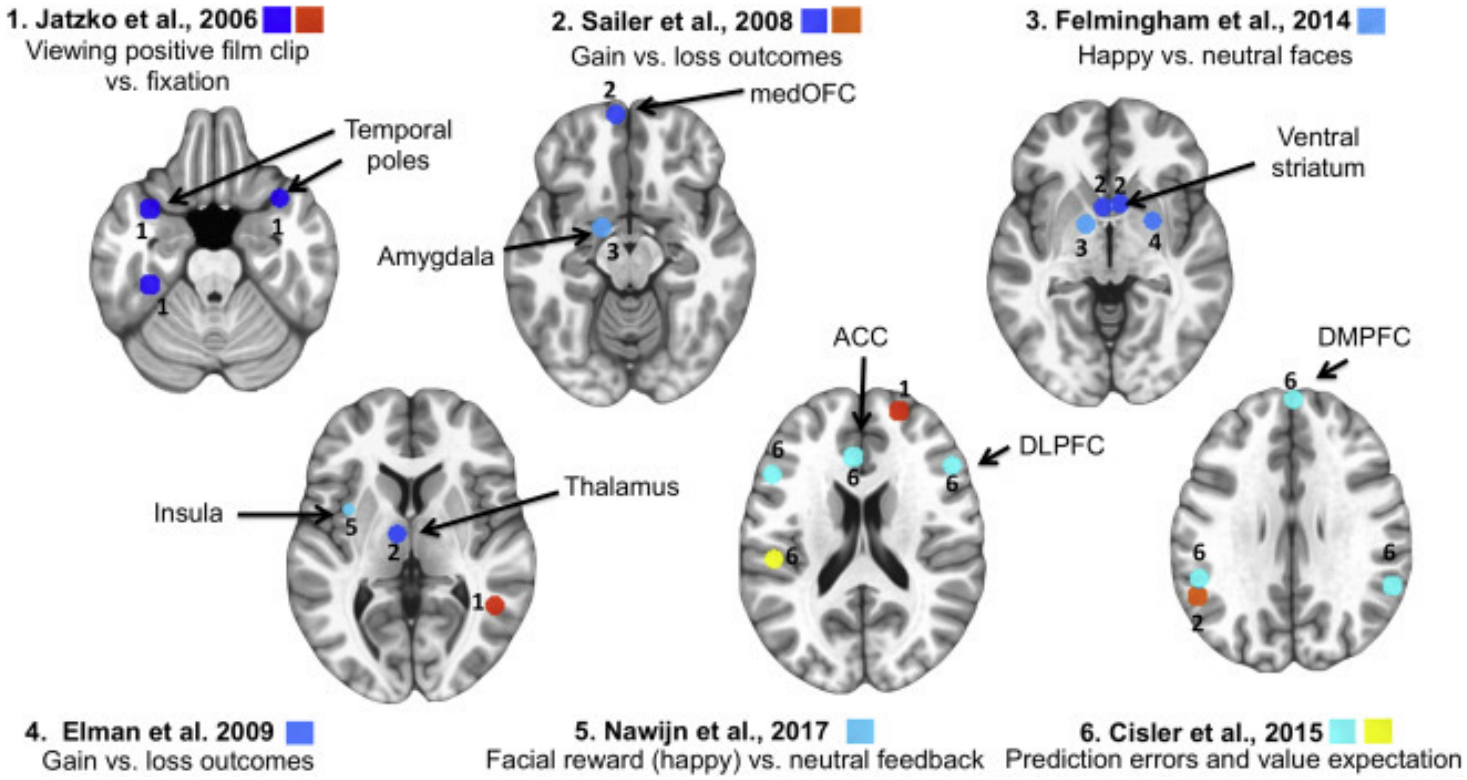
Role of stress



Fonzo, 2018

Role of stress

Functional atypicalities following PTSD



Fonzo, 2018

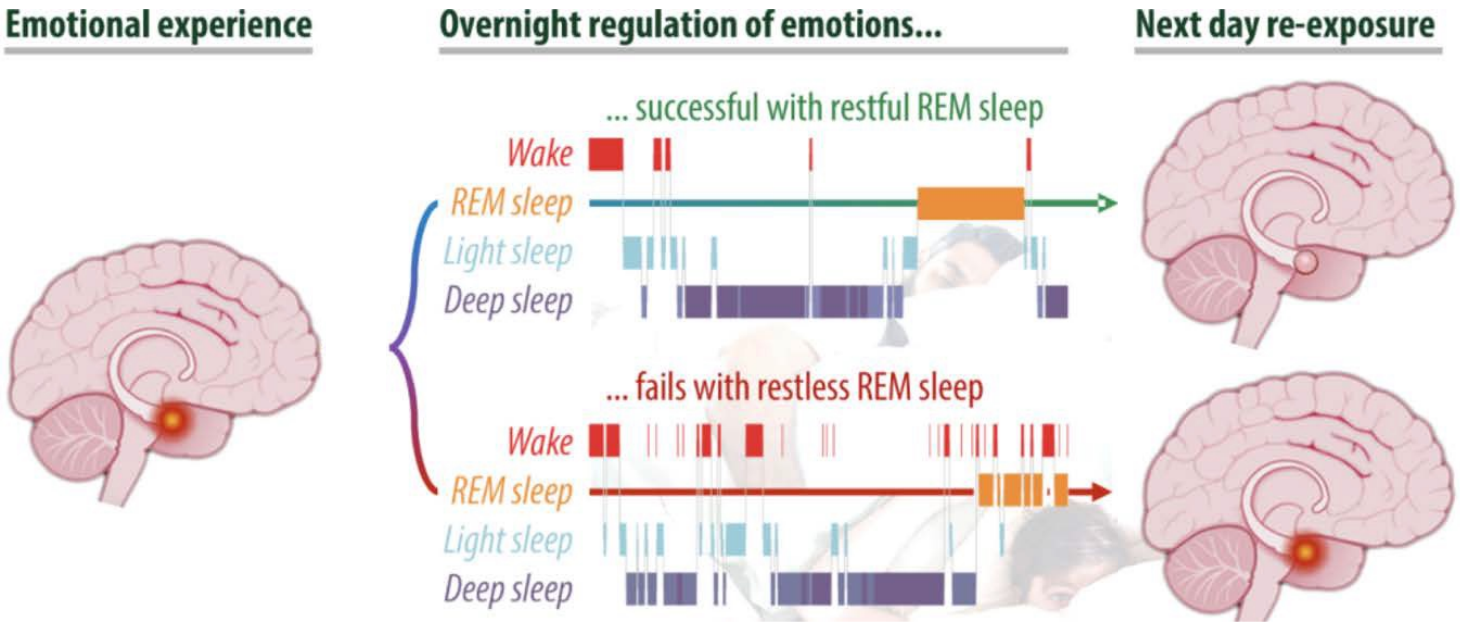
Role of sleep – REM

- 5th stage of sleep → starts after ~90 minutes of sleep & occurs 1-4x/night
- Activation in limbic system, amygdala, and dACC
  - Inhibition in locus coeruleus
- EEG similar to theta waves while awake
  - Main difference is muscle atonia
- Function:
  - Learning and memory consolidation in hippocampus
  - Dreaming state
  - Brain development (motor and sensorimotor system)
  - Appetite hormone regulation (leptin and ghrelin)
  - Alcohol, nicotine, & marijuana decrease REM sleep

Peever & Fuller, 2017

Role of sleep – REM

Restless REM Sleep – high # phasic events (i.e., stage transitions) and/or arousals



Wassing et al., 2019

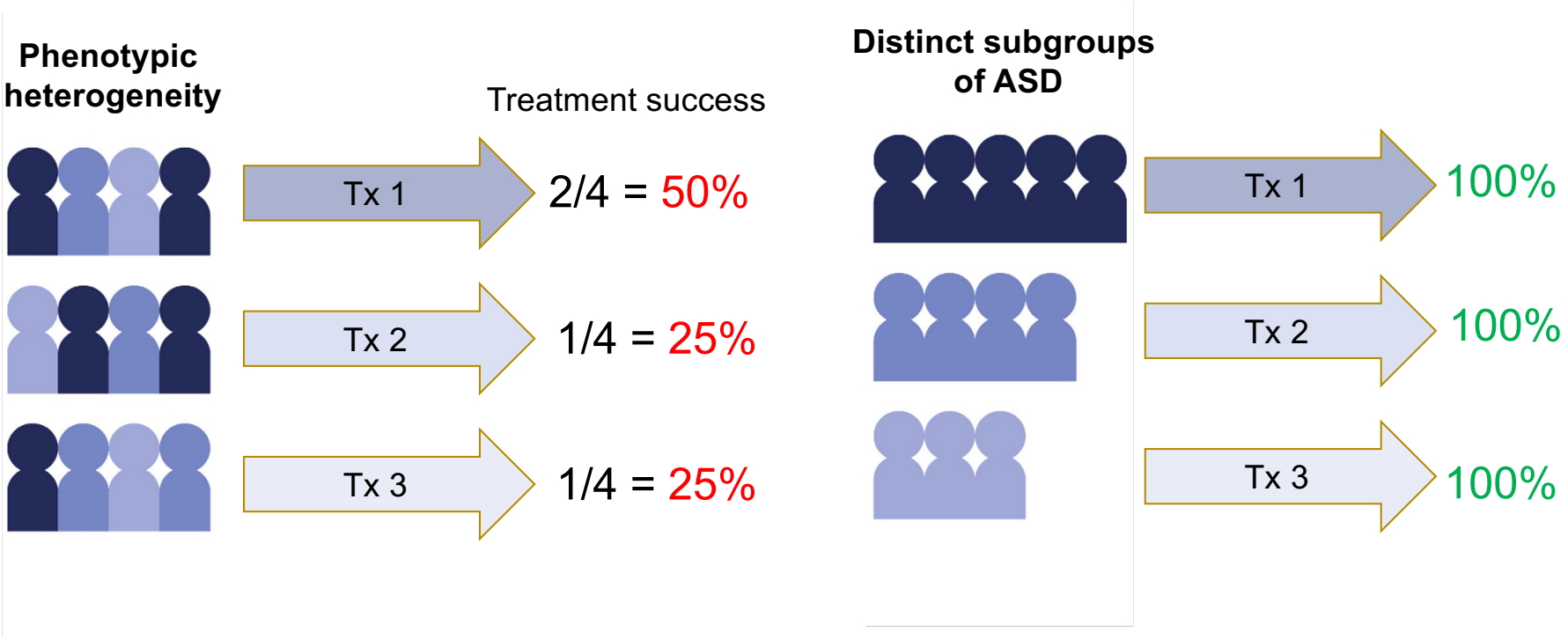
Papers for discussion next week:

- **Stress**:
  - Eshel, N., Maron-Katz, A., Wu, W., Abu-Amara, D., Marmar, C. R., & Etkin, A. (2021). Neural correlates of anger expression in patients with PTSD. *Neuropsychopharmacology*, *46*(9), 1635-1642.
- **Sleep**:
  - Simon, E. B., Vallat, R., Barnes, C. M., & Walker, M. P. (2020). Sleep loss and the socio-emotional brain. *Trends in Cognitive Sciences*, *24*(6), 435-450
  - Wassing, R., Lakbila-Kamal, O., Ramautar, J. R., Stoffers, D., Schalkwijk, F., & Van Someren, E. J. (2019). Restless REM sleep impedes overnight amygdala adaptation. Current Biology, 29(14), 2351-2358.

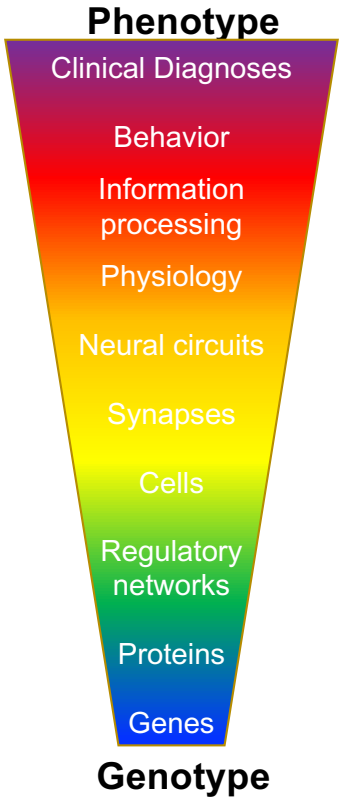
Affective neuroscience in treatment contexts

- Determine what arm of treatment (precision medicine)
- Measure effectiveness of intervention
  - Timing (e.g., dose effects) & extinguishing
- Neuroscience techniques *as* intervention

Precision medicine: Widespread heterogeneity in neurodevelopmental disorders

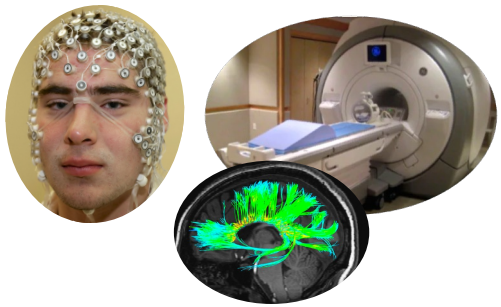


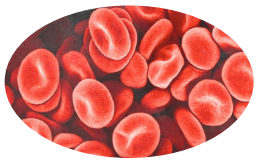
Precision medicine: What are biomarkers?



Autism spectrum disorder (ASD)

Diagnosed via behavior



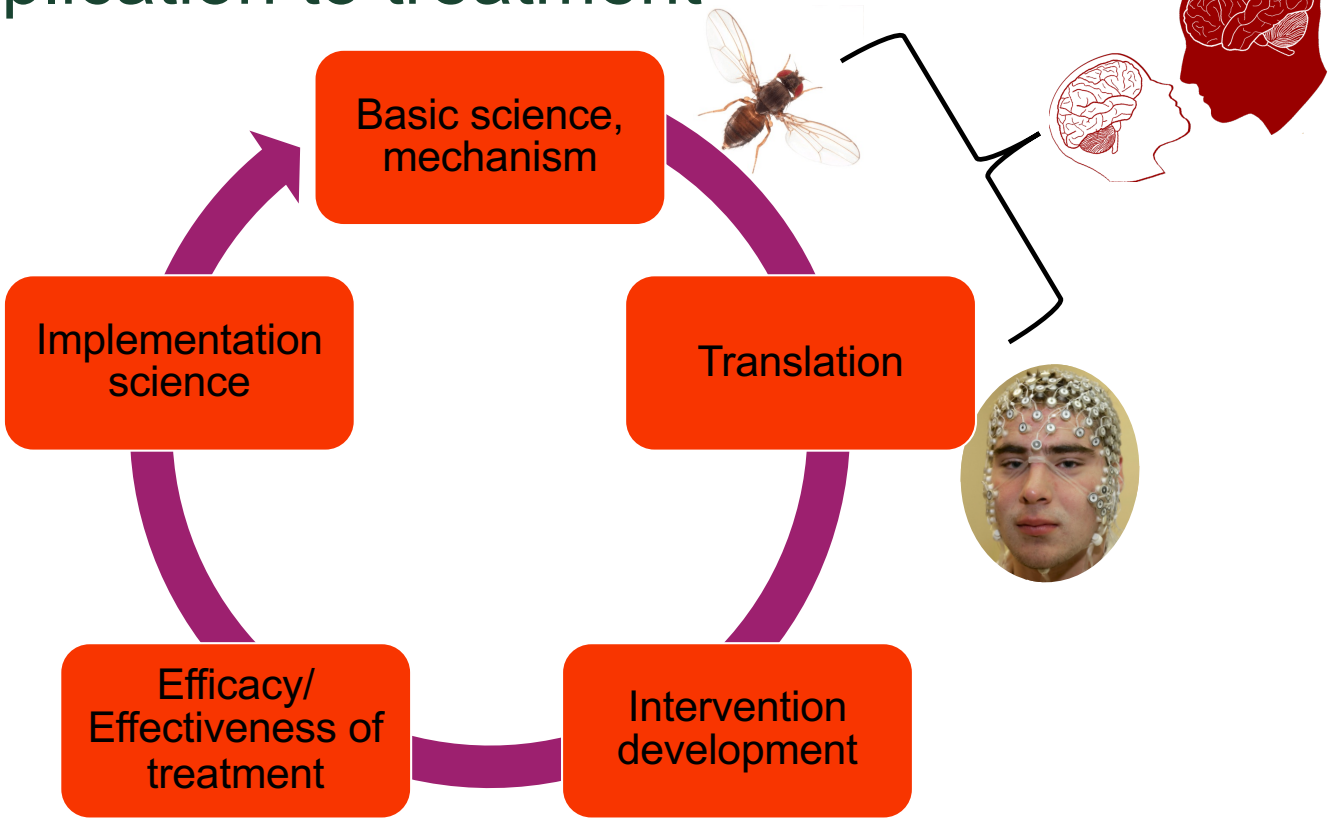


Biological indicators or markers of clinical diagnosis

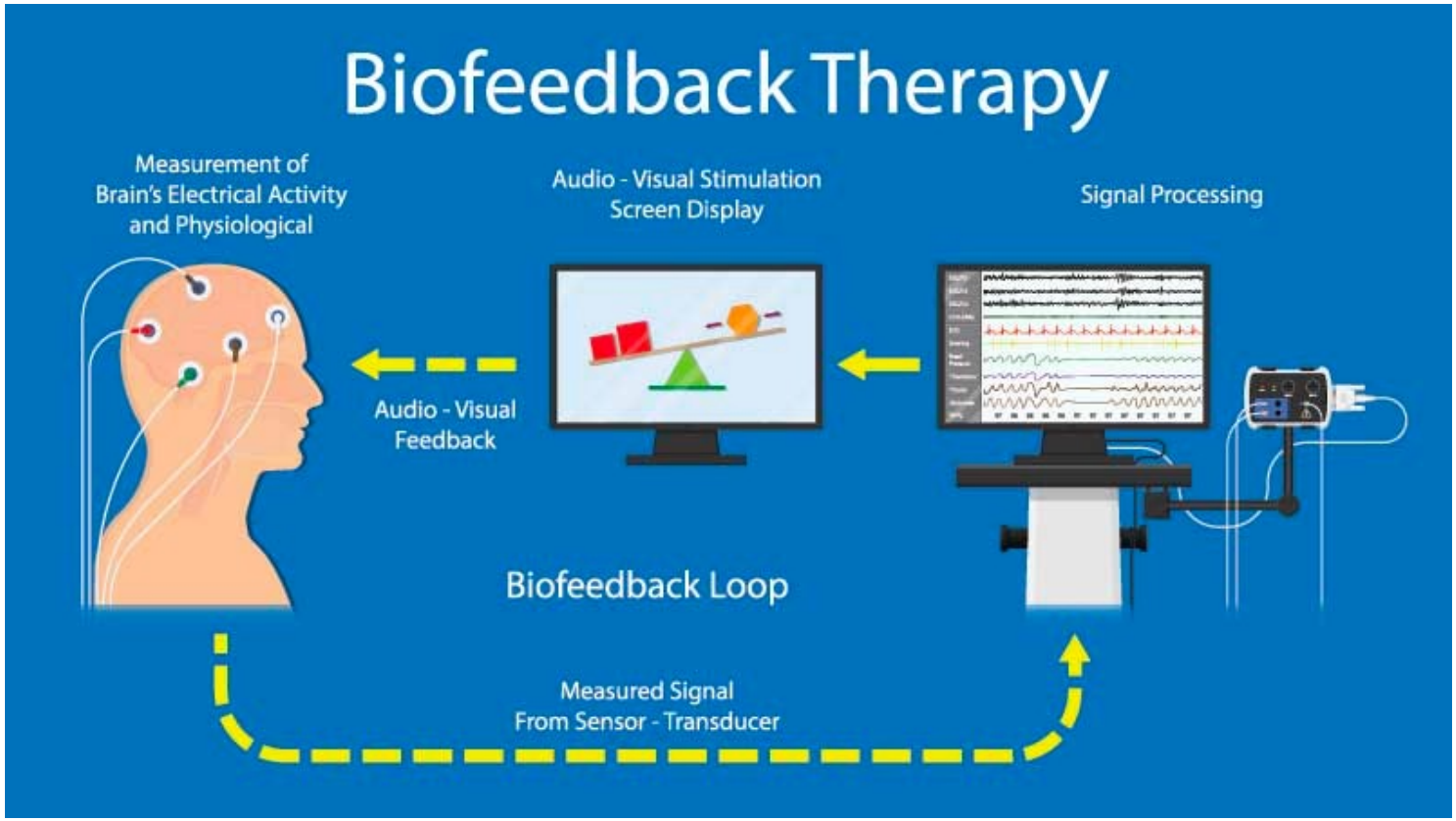
- Construct validity: *measures ASD*
- Discriminant validity: *does not measure NT*
- Predictive validity: *predicts differences between ASD & NT*

Precision medicine: Application to treatment

Brain Research Across Development (B-RAD) Lab



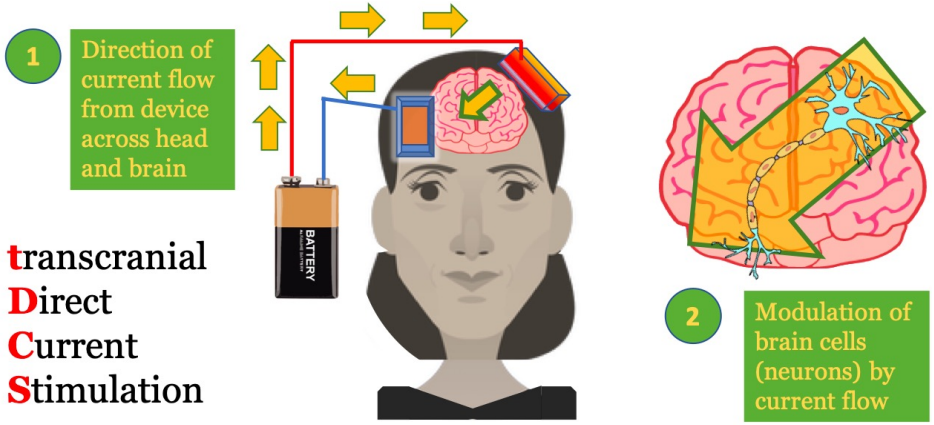
From perception to regulation intervention



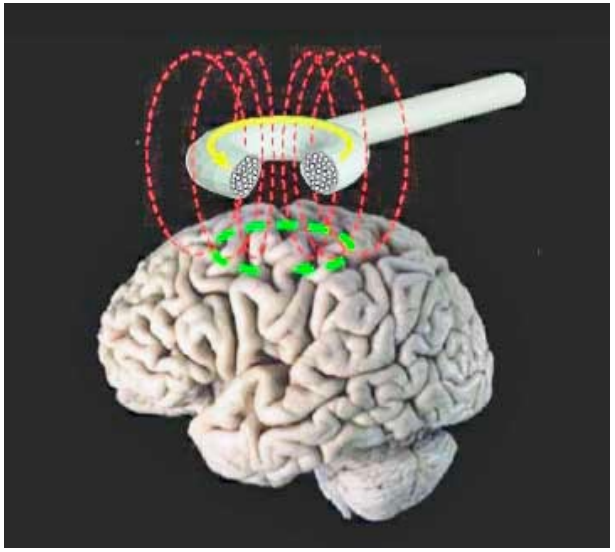
https://ucaststudios.com/re-training-your-brain-with-neurofeedback-therapy/

Biofeedback – stimulation methodology

- Transcranial magnetic stimulation (TMS)
- Transcranial electrical stimulation (tES)
  - Transcranial current stimulation (tCS)
  - Transcranial direct current stimulation (tDCS)
  - Transcranial alternating current stimulation (tACS)
  - Transcranial random noise stimulation (tRNS)



transcranial
Direct
Current
Stimulation



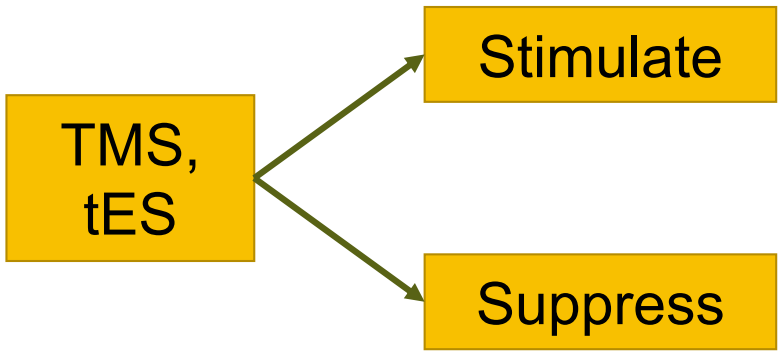
https://www.healthrising.org/blog/2020/07/20/tms-magnetic-stimulation-fibromyalgia-lasting-relief/

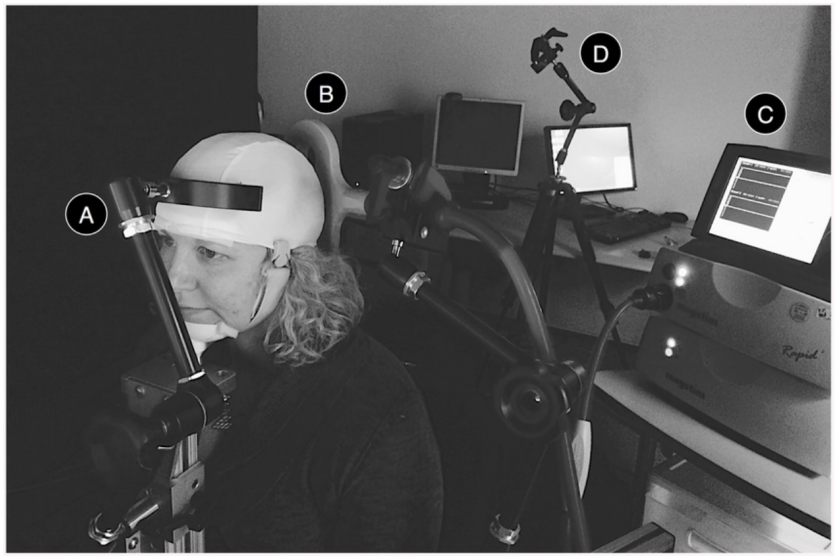
https://neuromodec.com/what-is-transcranial-direct-current-stimulation-tdcs/

Biofeedback – stimulation methodology

Two possible strategies:

1. Confirm brain function → Basic science
2. Correct brain function → Treatment

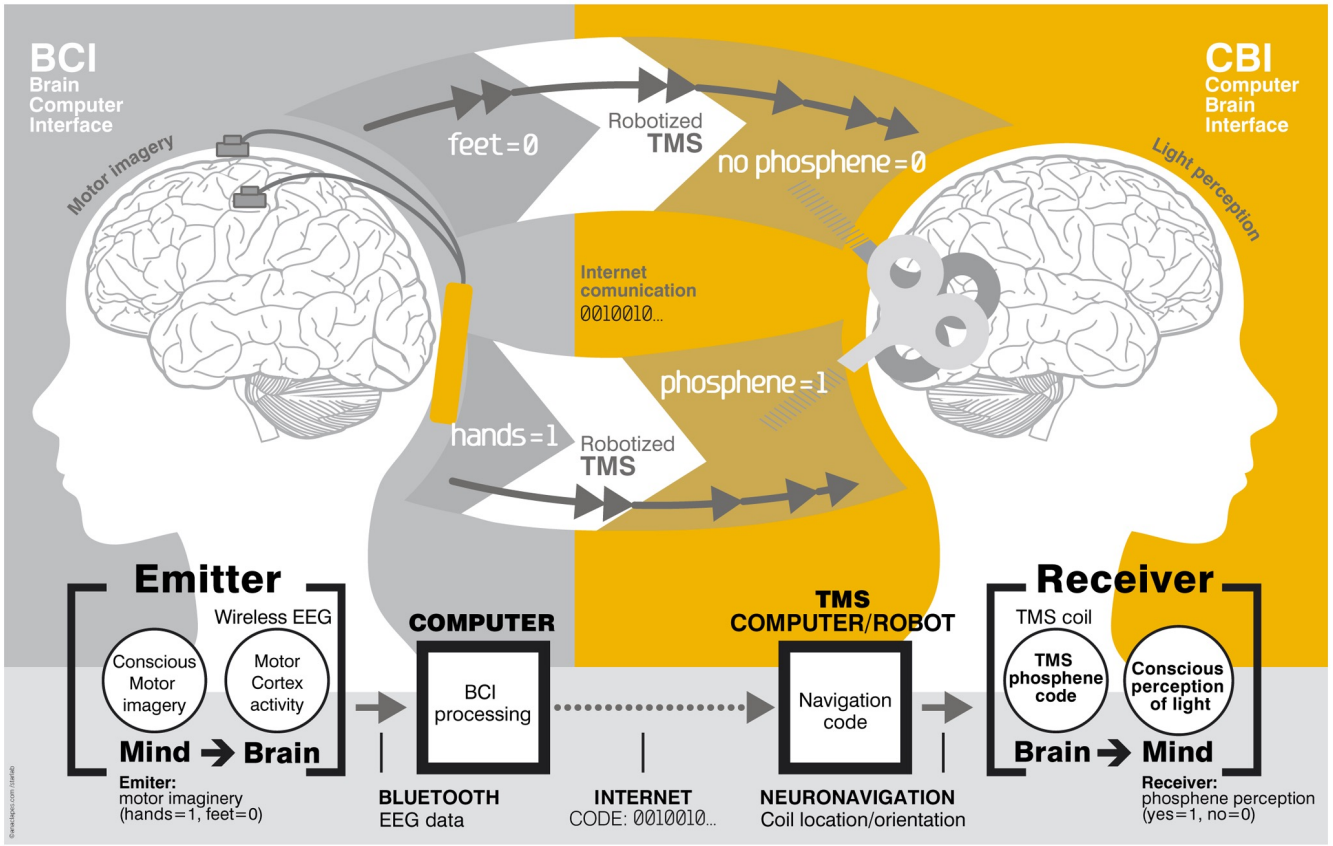




TMS Components of the BBI for the Inquirer. During the experiment, the inquirer sat in front of a computer screen on a BrainSight chair, with his or her head kept in place by a two-pronged head rest (A). A figure-of-8 TMS coil (B), connected to a MagStim Super Rapid2 stimulator (C) was positioned over the inquirer's occipital lobe to deliver visual stimulation in accordance with the respondent's answer. The head position and the coil position were carefully checked with the aid of a laser pointer (D).

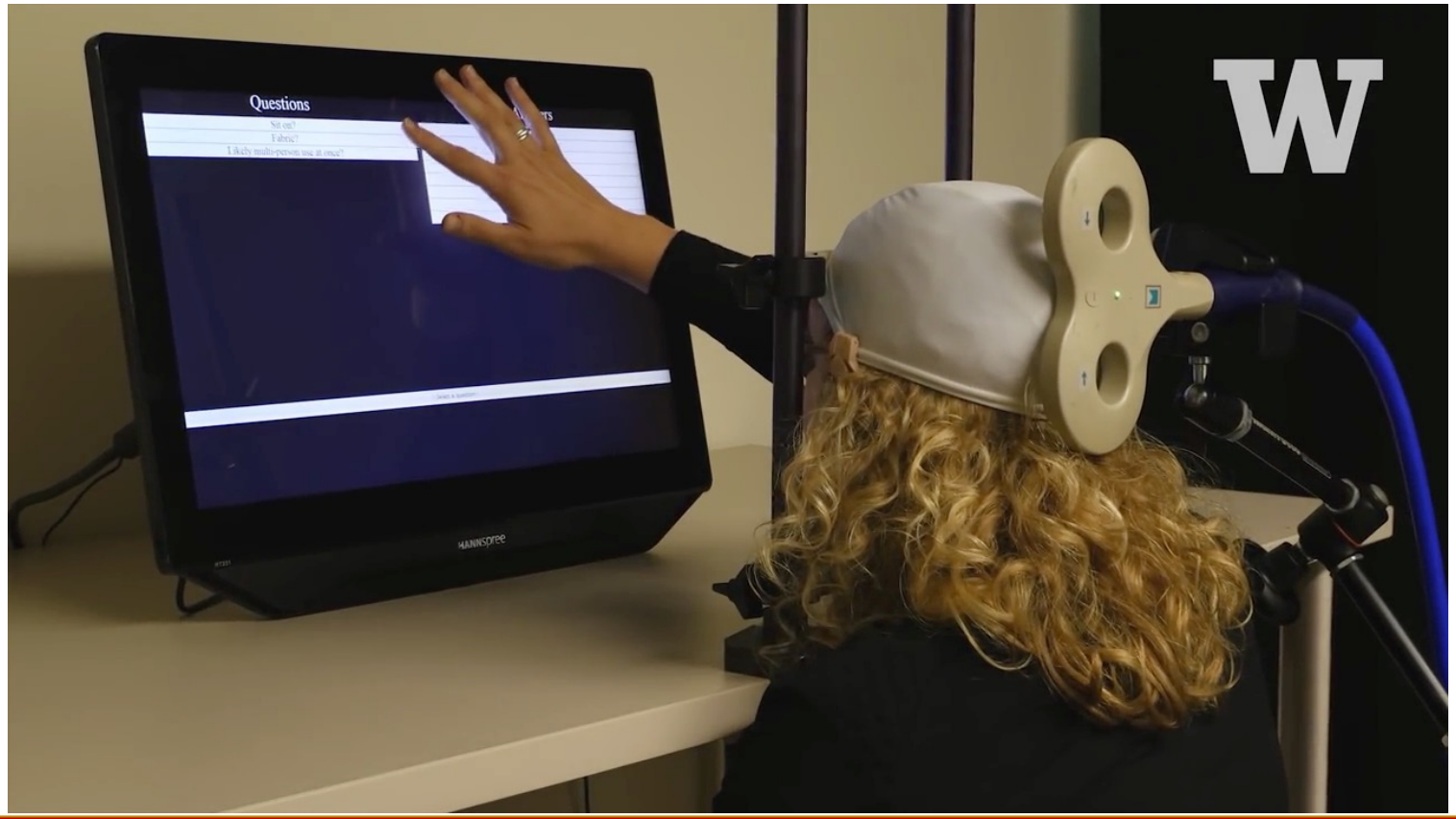
Stocco et al., 2015

Biofeedback – stimulation methodology



https://artsci.washington.edu/news/2016-08/mind-games

Biofeedback – stimulation methodology



https://artsci.washington.edu/news/2016-08/mind-games

Biofeedback – stimulation methodology

Current density can be impacted by:

- Individual factors: age, sex, tissue composition
- Electrode placement
- Current intensity
- Current phase / frequency
- Active vs. sham

Safety, tolerability, ethical considerations

- Side effects: Skin burning/irritation, headaches, fatigue
  - But both active & sham?
- Pediatric populations – phase, freq
- Unknown long-term consequences
  - Efficacy, but also ongoing side effects
- Limited regulation:
  - Approved by FDA in 2008
  - Technicians: do-it-yourself?

Reed & Kadosh, 2018

Considerations for affective neuroscience

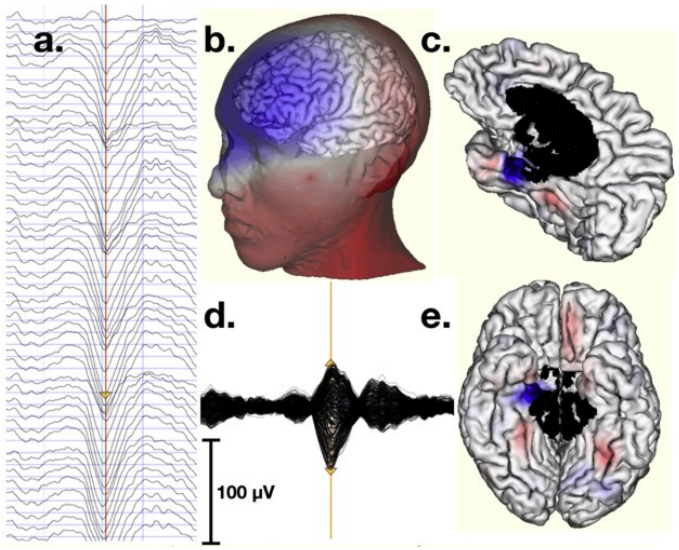
- Implemented in basic science
- Effective stimulation of emotional regions (e.g., limbic: AMY, insula)?
  - TMS/tES depth and location
  - Duration of stimulation
- Pediatric and special populations

Example: tES of limbic cortex during sleep

- **Premise**: Impaired sleep → mild cognitive impairment (MCI) → Alzheimer's disease (AD)
  - Slow-wave sleep oscillations (SO; non-REM stage 3, N3) clears glial-lymph metabolic toxins

SO originate in PFC and travel across cortex→ unpublished work indicates anterior limbic, which can be captured at frontopolar/inferior frontal sites

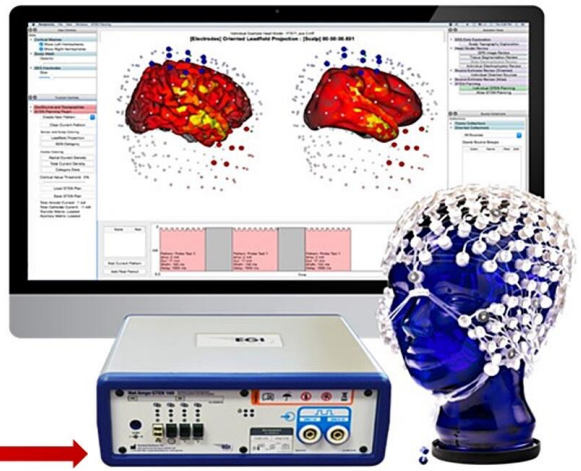
Goal 1: Stimulate ant.limbic → Enhance N3 sleep
Goal 2: Lower tES current levels from usual 1-2 mA to 0.5 mA

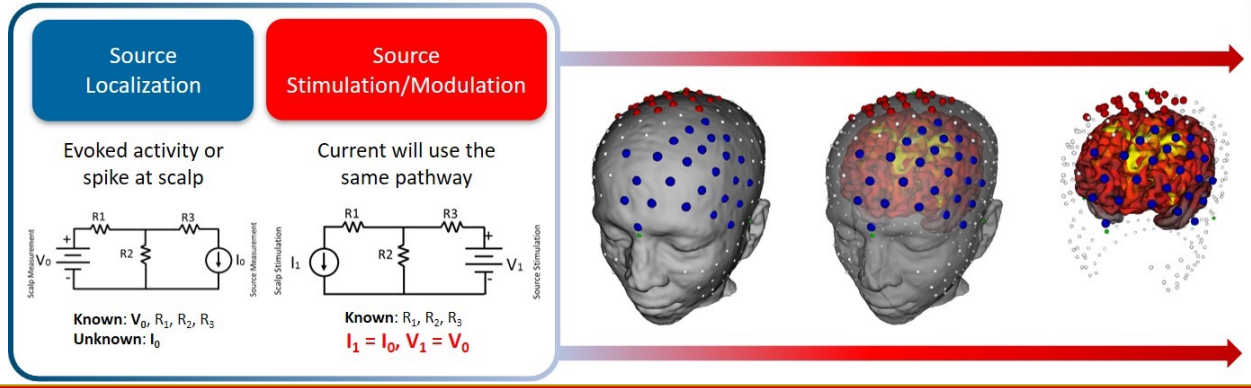


Hathaway et al., 2021

Example: Subjects, design

- 10 adults (age 20-67 years)
- 3 overnight sessions w/EEG + TMS
  - 1st adaptation night
  - 2nd sham or active (CB)
  - 3rd sham or active (CB)



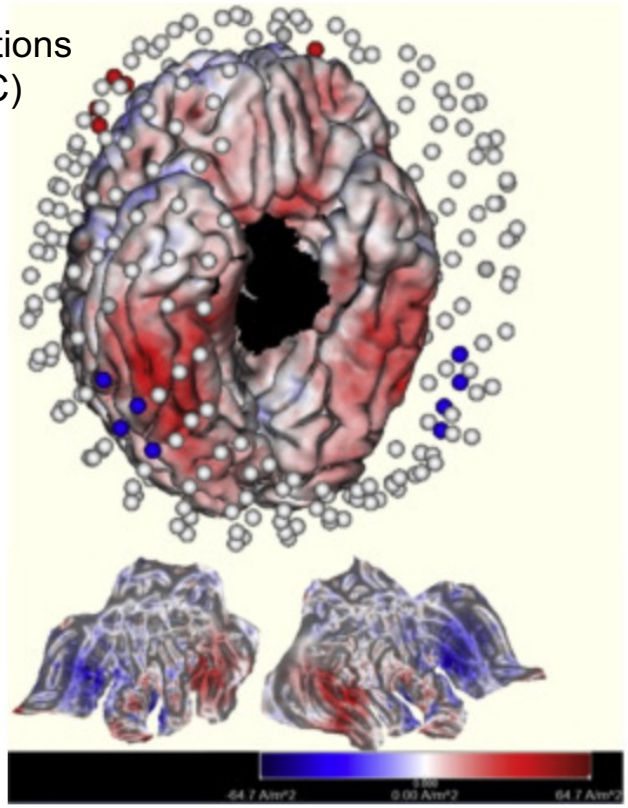


This modeling and source localization were computed with a head conductivity model constructed for each subject.

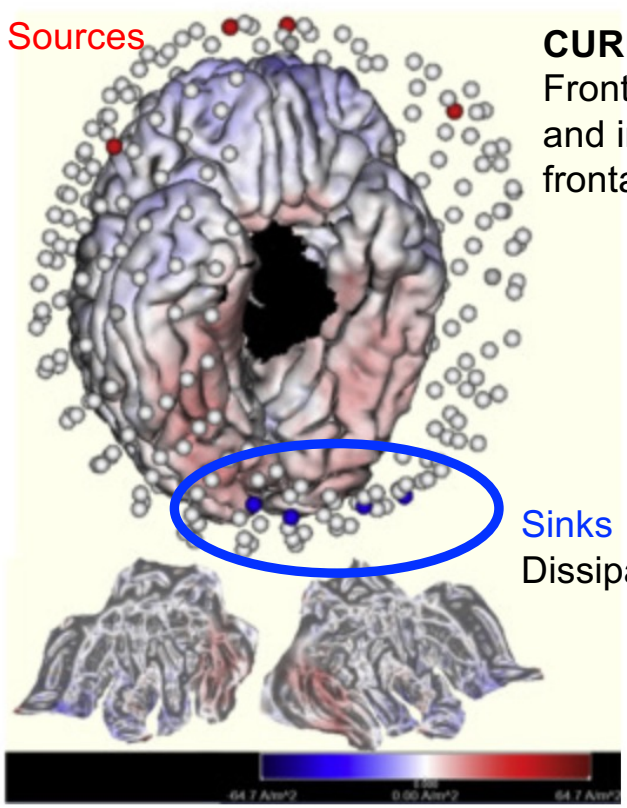
Hathaway et al., 2021

Example: Subjects, design

Previous locations for tES (dlPFC)



Sources



CURRENT STUDY
Frontopolar (Fp1/2) and inferior lateral frontal (F9, F10)

Sinks
Dissipate heat

Hathaway et al., 2021

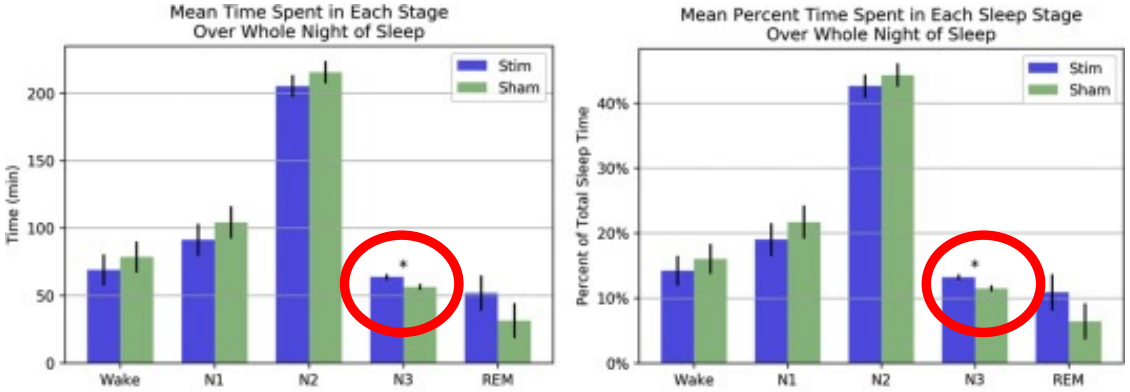
Example: Subjects, design

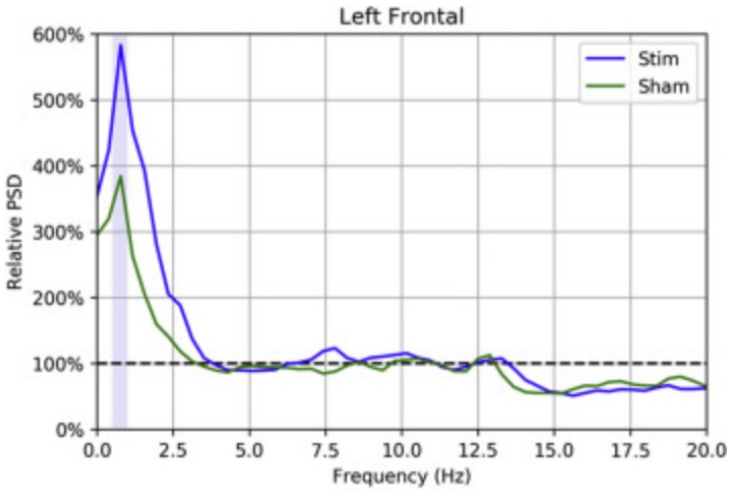
- Source localization based upon each subject's head
- Use machine learning to detect sleep stages
  - Training, validation, test
  - Just as accurate (84%) as human raters (40-82%)
- Score amount of time in sleep stages (excluding any stimulation periods)

Hathaway et al., 2021

Example: Results

Increased time and % of total sleep in N3 stage





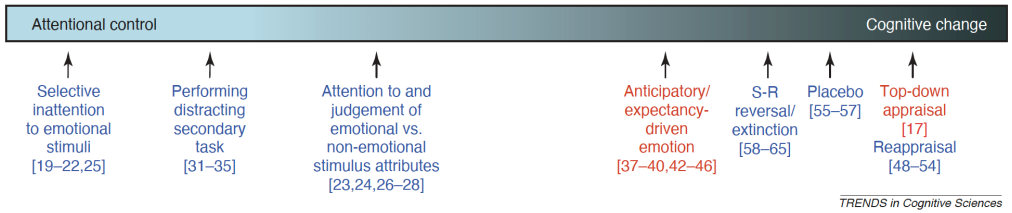
Goal 1: Stimulate ant.limbic → Enhance N3 sleep: **Increased time and % of total sleep in N3 stage**

Goal 2: Lower tES current levels from usual 1-2 mA to 0.5 mA → **Yes, successful**

Hathaway et al., 2021

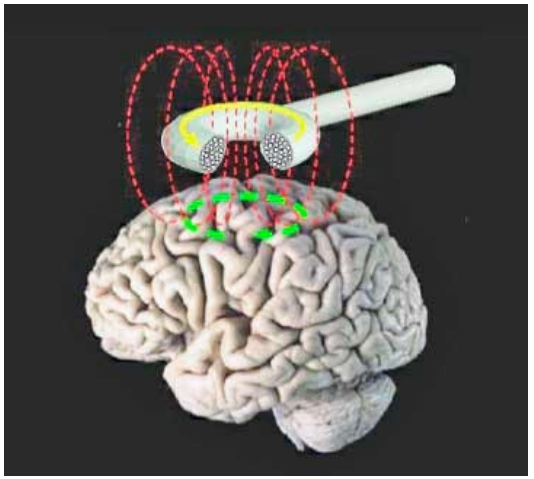
Treatment

Cognition and attention can modulate emotion perception and emotion regulation



How would you use these techniques in your populations?

Direct stimulation (or suppression) of the brain may also modulate regulation



Questions?

- Next class period – developmental considerations: any specific populations?