Technical aspects of transcranial electrical stimulation:

Hardware, devices, and procedures

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Disclosures

- Adam J. Woods, PhD *does not have any financial arrangements or affiliations with any commercial entities whose products, research or services may be discussed in these materials.*

Technical aspects of transcranial electrical stimulation

Outline

Part 1: Devices

Part 2: Electrode Hardware

Part 3: Procedures

Woods et al. (2016). A technical guide to tDCS, and related non-invasive brain stimulation tools. *Clinical Neurophysiology*, 127: 1031-1048.

Technical aspects of transcranial electrical stimulation

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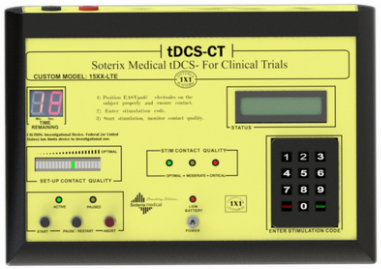
Part 3: Procedures

Low Current tES Devices

- Wide range of marketed devices
  - Currently a limited set of certified low current tES-stimulators available
  - Important to use a professionally engineered medical device designed to deliver current to the head/spine



Key features to look for:

- Constant and controlled current delivery
  - Exactness of current delivered is critical
  - Voltage controlled (constant voltage) devices are not appropriate for tES
- Reasonable and safe current ceiling
  - Devices do not need to be able to stimulate at 1 amp for tES
- Blinding and sham features
  - For research or clinical trial applications
- Current ramp function
- Programmable (if desired)
  - Current intensity, duration of stimulation, etc.
- Impedance/contact quality
- Other safety features
  - Battery operation, low battery warning, abort function, etc.

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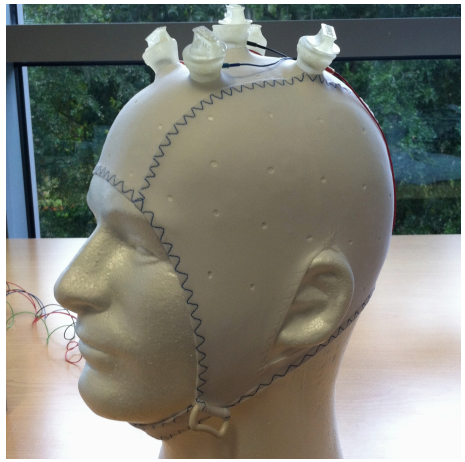
Part 2: Electrode Hardware

Part 3: Procedures

Electrode Hardware

- Conventional Electrodes
  - Electrode Assembly
  - Electrode Size
  - Electrode Type
  - Wires

- HD/Multi-electrode
  - Electrode Assembly
  - Electrode Size
  - Electrode Type
  - Wires



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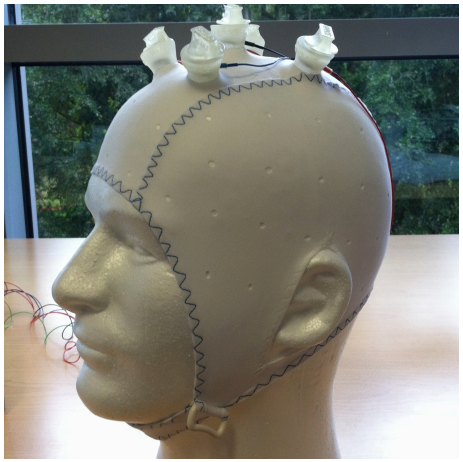
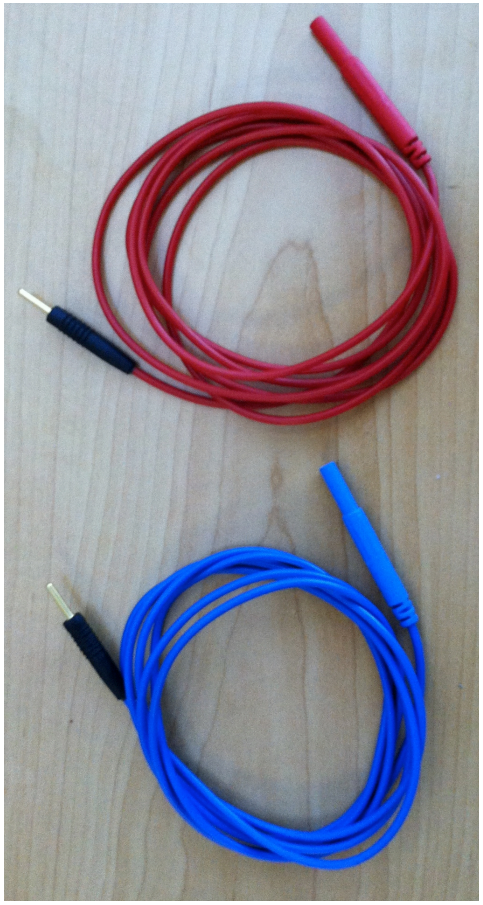
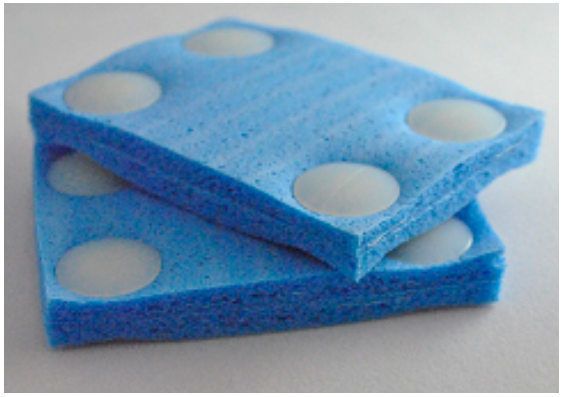


Conventional Electrode Assembly

- Electrode
- Sponge
- Wire





Conventional Electrode

- Biocarbon Electrodes
  - Most common

Conventional: Sponge Size

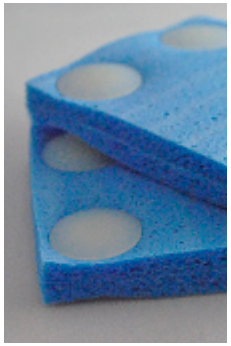
- A variety of sizes
  - 5x5 cm
  - 5x7 cm
  - 5x10 cm
  - 10x10 cm
  - Other sizes available

- Why different sizes?
  - Control of current concentration/intensity
  - Method for altering the “general” focality of current delivery

Sponge/Electrode Integrity

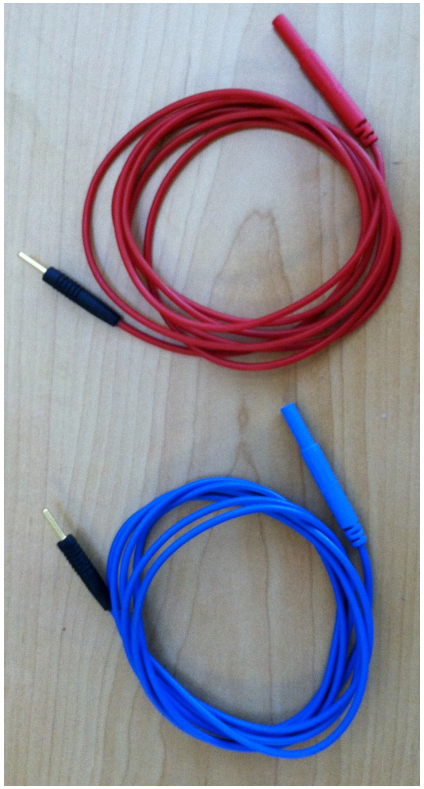
- Biocarbon Electrodes and Sponges

- Conventional 1x1
  - Rubber electrodes
  - Sponge pads
    - Single use
    - Multi-use



Electrode Wires

- Manufacturer specific device connection
- Common electrode connection terminal
- Careful to remove by grasping at terminal, not the wire



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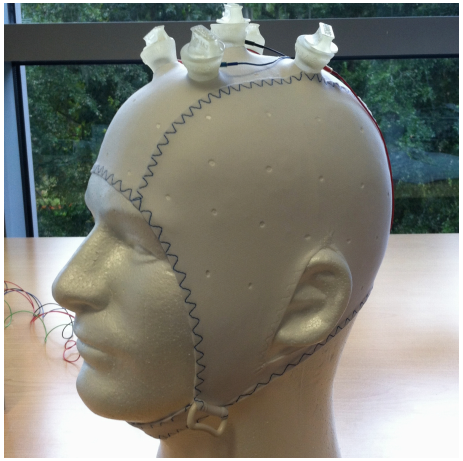
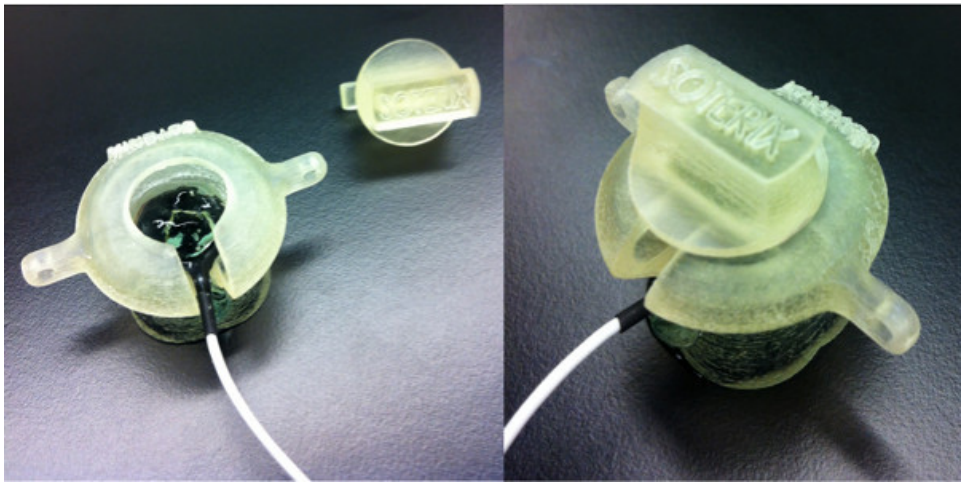


HD or multi-electrode assembly

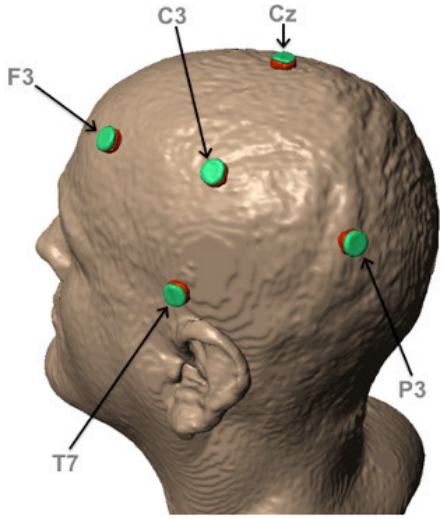
- Electrodes

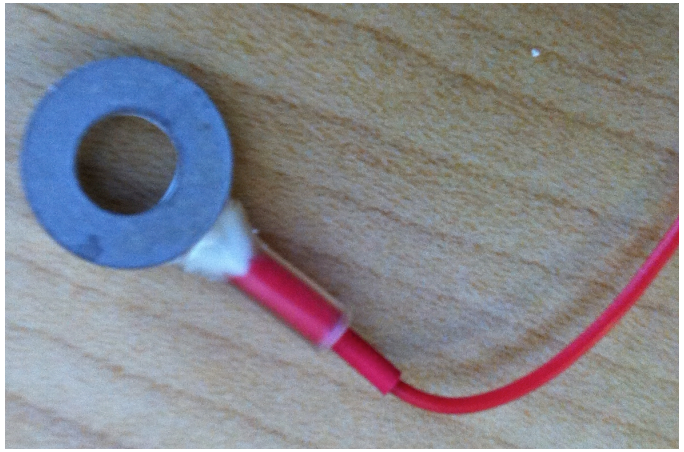
- Electrode holders



Electrode Type

- Ag/AgCl Electrode
  - Must be replaced after two uses in center position of “4x1 montage”





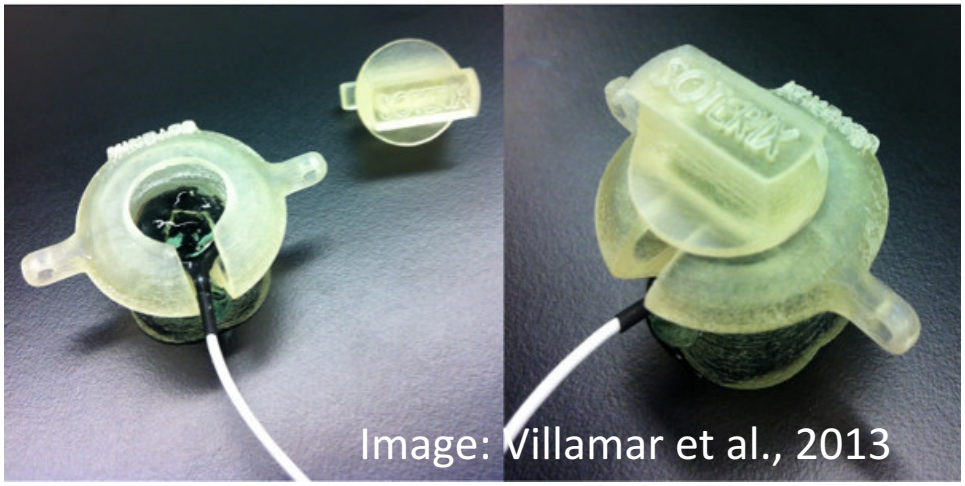
Ag/AgCl Electrode Integrity

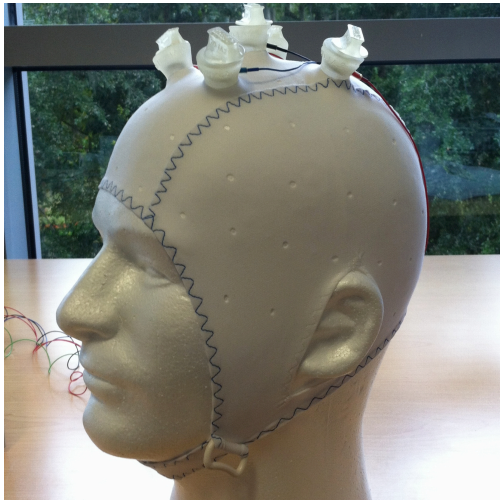
- Chipped Ag/AgCl electrodes
  - Do not use
  - Can also break during insertion holder

- Ag/AgCl electrodes must be replaced after certain number of uses
  - Excessive corrosion/blackening of electrodes should cue replacement
  - An electrode “use log” is helpful for tracking number of uses in the center position

Electrode Holder

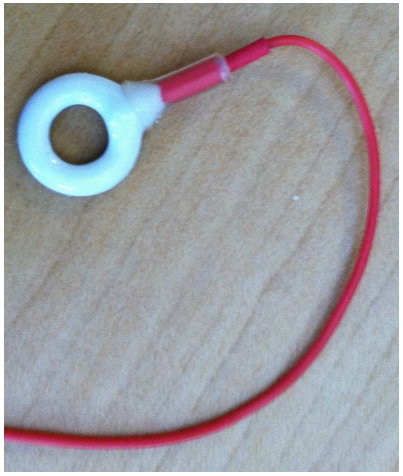
- Plastic Holder for positioning of electrode
- Fits within standard EasyCap or other similar EEG-style caps

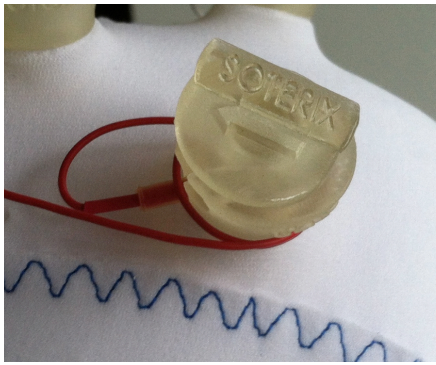




Wires

- Fragile
- Highest point of failure
- Methods for reducing wire strain
  - Wrapping wires around electrode holder
  - Clipping wire junction to the participants shirt or chair





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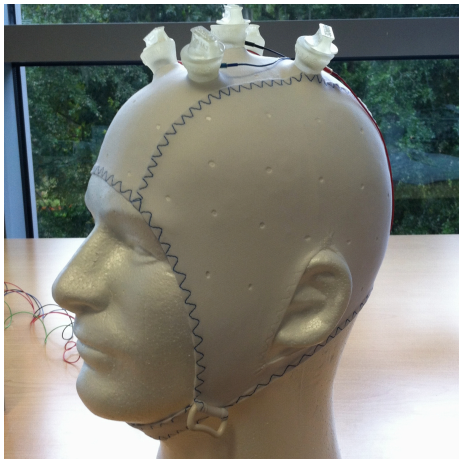
Procedures

- Conventional Application
  - Contact Medium
  - Electrode Location
  - Electrode Orientation
  - Electrode Drift
  - Scalp Contact
  - Impedance

- Ag/AgCl Application
  - Electrode Location
  - Contact Medium
  - Impedance



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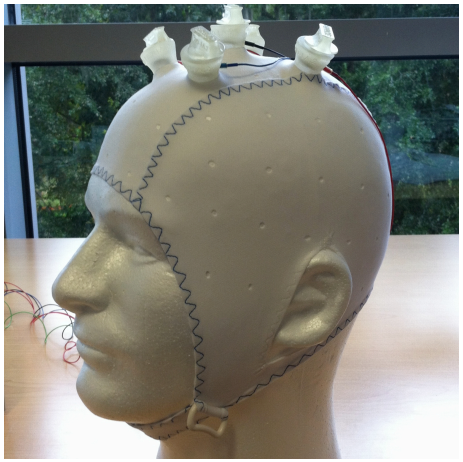
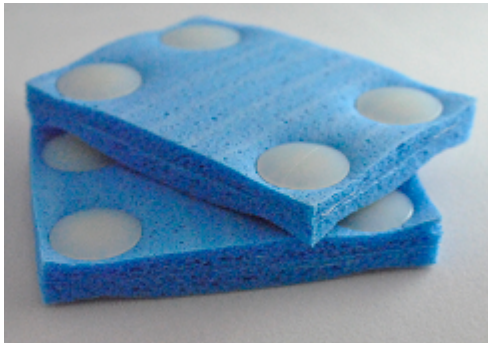
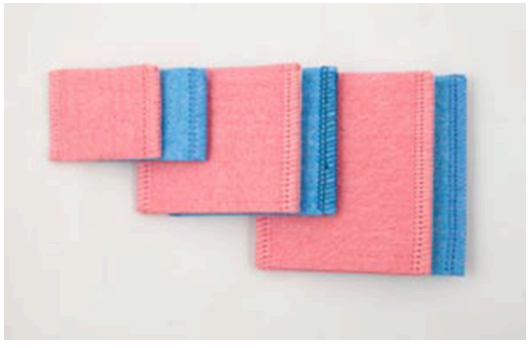


Contact Medium: Saline: 0.9% Solution

- Proper saturation of sponge
  - ~8 mL recommended for 5 x 7 cm
  - Eye dropper gives best control over delivery (~4 mL/side)
- Do NOT over saturate
  - Bridging
- Do ***NOT*** apply stimulation to a dry sponge
  - Sponges designed to hold saturation ~20 minutes
- ***NEVER*** use water





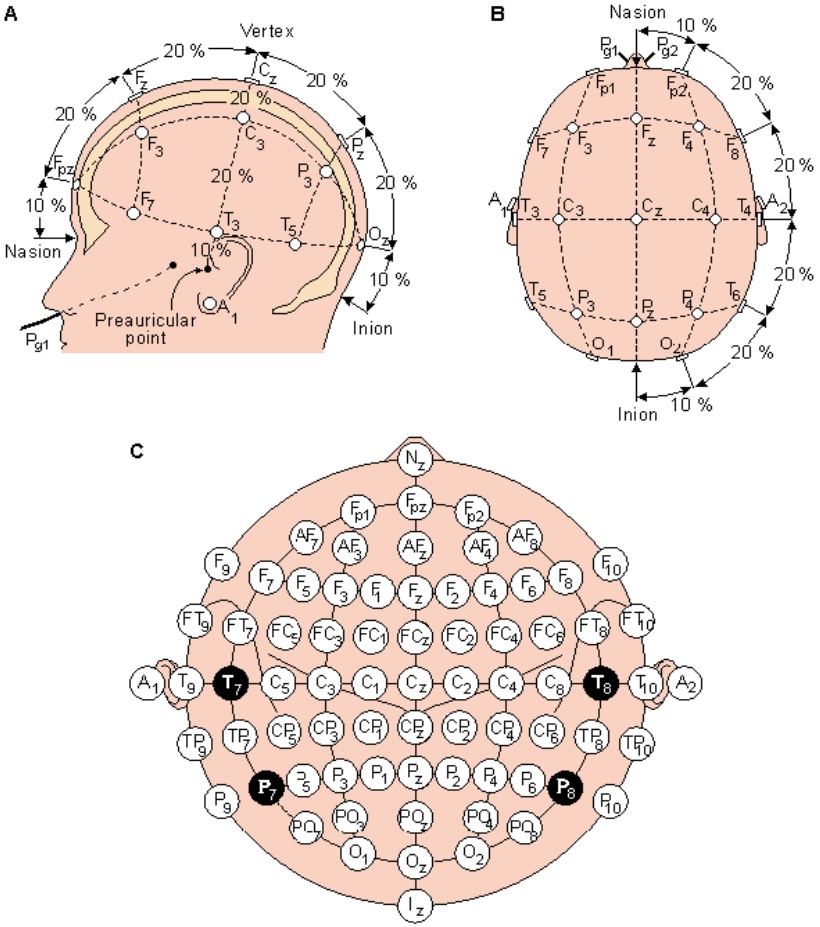
Electrode Paste

- Alternative to Saline
  - Pros
    - Stability over time
    - Less likely to “drip”
    - Sensation differences
      - Decreased sensation with 3+mm layer

  - Cons
    - More difficult to obtain low impedance levels
      - Necessary to massage paste into scalp area prior to placing paste covered electrode
    - Thick (~3mm) coating of paste must be maintained
      - Easy to press electrode such that paste thickness in decreased

Electrode Location

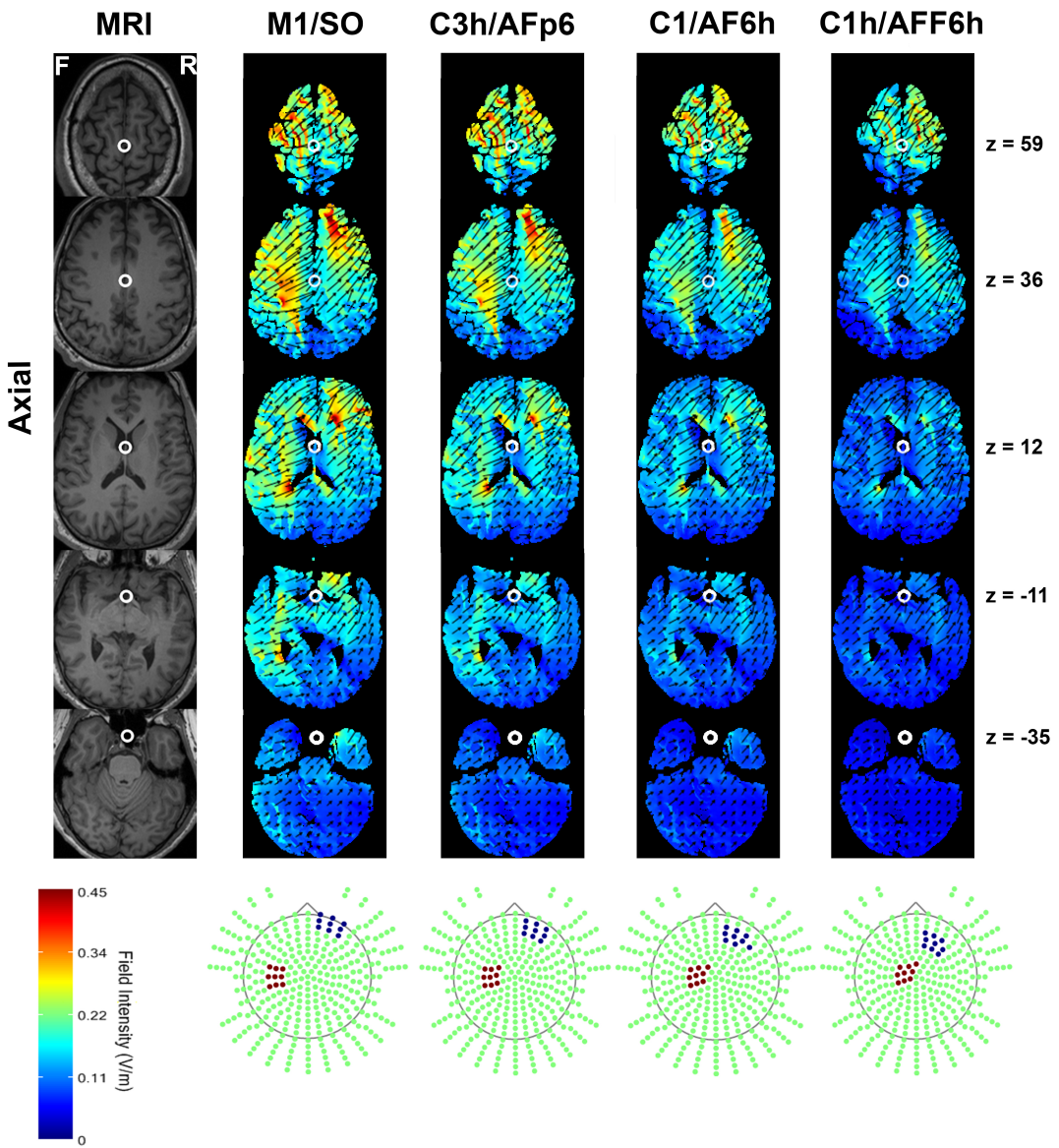
International 10 – 20 Measurement System



Electrode Drift

- When using straps to secure electrodes
  - Straps may drift over time if not properly secured
  - Fine or oily hair have higher rate of drift
  - Use the heads anatomy to your advantage
  - Use cross-straps and chin straps if needed on a particular montage
  - Keep securing strategy consistent across all subjects
  - **Place marks at the bottom edges of electrodes and measure pre-post drift**

Electrode Drift: Models



Woods et al., Brain Stimulation 2015

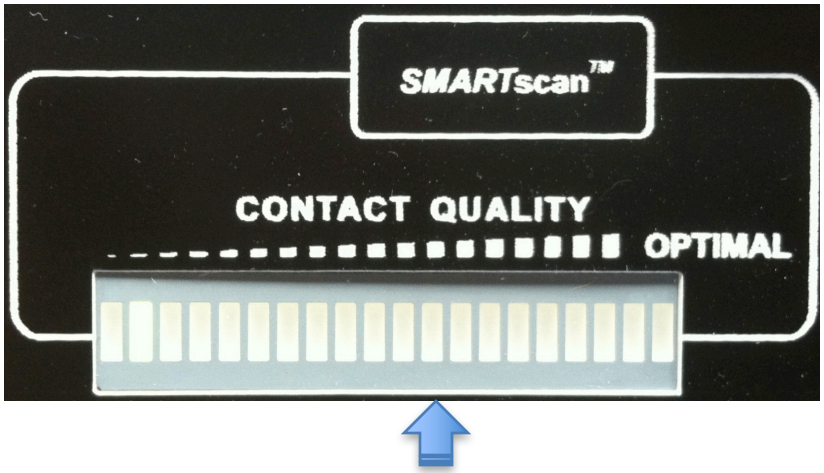
Impedance

- Greatest impediment to impedance:
  - Hair
- Do not over-soak sponges with saline
- Use all plastic hair clips to secure hair if needed
- Attempt to provide as much contact with the skin as possible
- Be careful not to stray from the intended electrode site

Impedance/Contact Quality

- Impedance-based device
  - Aim for <15 kOhm before start of stimulation
  - Impedance will improve during stimulation
  - Good to record impedance at beginning, middle, and end of stimulation period

- Contact quality device
  - Within '<10 bars' of optimal
  - Rapid improvement with stim



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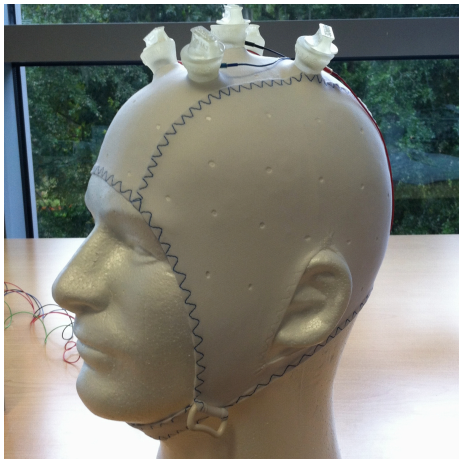
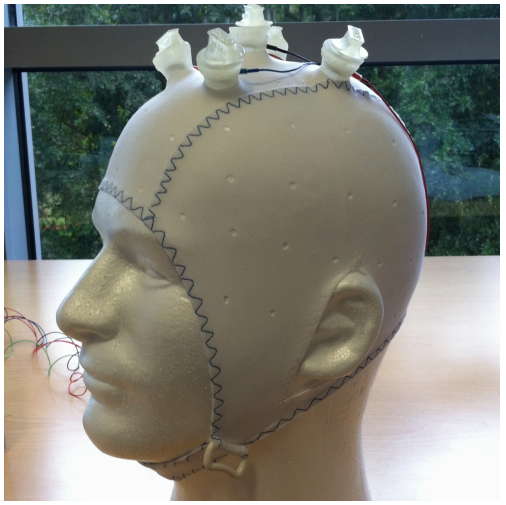


Ag/AgCl electrode location: Cap Fit

- Easy Caps or other similar caps
  - Head-size specific
  - Measure head circumference
  - Select appropriate size



- Mark at least Cz and the center location of the 4 x 1 montage using the 10-20 location prior to cap placement

Contact Medium: Conductance Gel

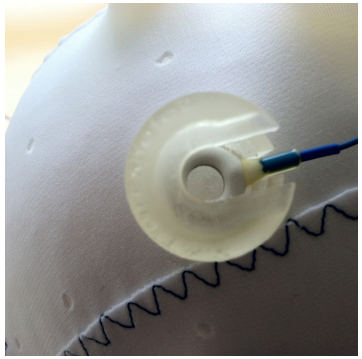
- Conductance gel (e.g., Signa gel) will saturate the skin over time
  - As the gel saturates the skin, impedance improves
  - Use gels tested by manufacturers to be safe for stimulation

- Careful not to overfill holder such that gel escapes bottom of holder
  - Avoid shunting


Image: Villamar et al., 2013

Impedance: < 1.5 Quality Units

- Greatest impediment to impedance:
  - Hair
  - Expose scalp using end of blunt tipped syringe
  - Keep impedance consistent across electrodes



- Attempt to minimize air pockets in gel

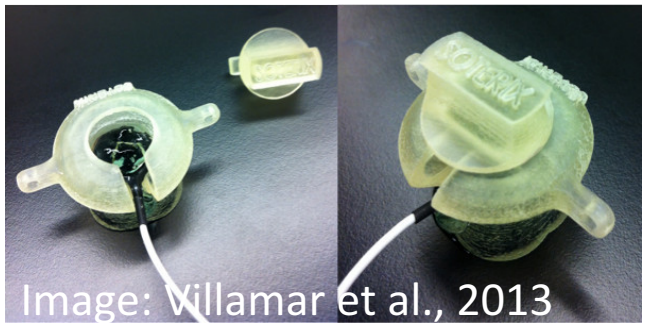


Image: Villamar et al., 2013

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Take home

- **Rigor and reproducibility are in the details**
- Minimize variation in application
- Use measureable approaches to application
- Choose a device designed for application of tES on the head/spine
- Do NOT oversaturate sponges
- Record impedance/contact quality
- Record electrode drift
- Careful about strap tightness
- 10-20 location is an easy and consistent guide for electrode placement
- Report exact details of application methods