Neurofeedback Review

Background, Literature, and Potential MEG Projects

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Agenda

- **Overview of Neurofeedback**
- EEG Neurofeedback and Practice
  - Research Efficacy
  - Clinical Treatment
  - Personal Experience
- fMRI Neurofeedback
- MEG Neurofeedback
- Current Ideas & Considerations

Overview of Neurofeedback

- “[In EEG], neurofeedback is a process in which simple auditory and visual feedback guide the brain gradually to make more or less of specific brainwave frequency bands, and/or to enhance connectivity between two regions of the brain.” (PeakBrain, 2019)

- Advances Today:
  - Many EEG studies and therapeutic practices
  - Several real time fMRI Studies
  - Few real time MEG studies

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EEG Neurofeedback & Practice

- <u>Research supporting efficacy of neurofeedback in EEG</u>
  - NF training in upper **alpha** frequency band improves cognitive performance (*Benedikt Zoefel, René J. Huster and Christoph S. Herrmann, 2011)*
  - Improving new memory consolidation through NF **theta** enhancement (*R. Rozengurt, L. Shtoots, A. Sheriff, O. Sadka and D. Levy, 2017)*
  - Increased perceptual sensitivity with **SMR** training and increased reaction times with **beta1** training (*Egner, T., & Gruzelier, J. H. (2001). NeuroReport, 12, 4155–4159)*

EEG Neurofeedback & Practice (cont.)

- <u>Research supporting efficacy of neurofeedback in EEG</u>
  - NF training in upper **alpha** frequency band improves cognitive performance (*Benedikt Zoefel, René J. Huster and Christoph S. Herrmann, 2011)*
    - 24 subjects; 14 NF trained on five sessions within 1 week on upper alpha frequency band; 10 control
    - Neurofeedback task used colored squares
    - Cognitive ability tested by mental rotation task before and after neurofeedback
    - Results:
      - Found an increase in upper alpha in last NF session for experimental group.
      - Experimental group also showed better cognitive performance
      - Independent training
      - Trainability → long term implications
        - Linear increase of upper alpha amplitude

EEG Neurofeedback & Practice (cont.)

- <u>EEG biofeedback for clinical treatment</u>
  - Inattention, impulsivity, and hyperactivity for ADHD *(Arns et al., 2009)*
  - Communication and executive functioning for Autism & Aspergers *(Kouijzer et al., 2009)*
  - Reduced symptoms such as nightmares, anxiety, and depression for PTSD *(Smith et al., 2008), (Peniston & Kulkosky, 1991)*
  - Reduced symptoms and fatigue for depression *(Choobforoushzade et al., 2014) (Choi et al., 2011)*

EEG Neurofeedback & Practice (cont.)

- Personal Experience

  - Peak Brain Institute
    - Typical session:
      1. QEEG “Brain Mapping”
         - Specified protocol for each patient
      2. Discussion with clinician about needs
      3. Neurofeedback training
         - At least 3-4x a week, 20-30 minutes per session
         - Depending on need, around 20-40 sessions
         - Protocol change if needed after every session
    - EEger and Bioexplorer
      - Driving task
      - Flying task
      - Puzzle task

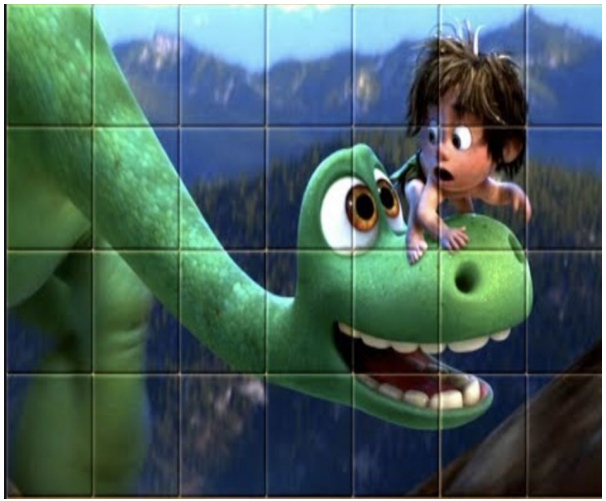
EEG Neurofeedback & Practice (cont.)

- EEG Tasks (Similar POV to these images)

Driving Task

Flying Task

Puzzle Task



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fMRI Neurofeedback

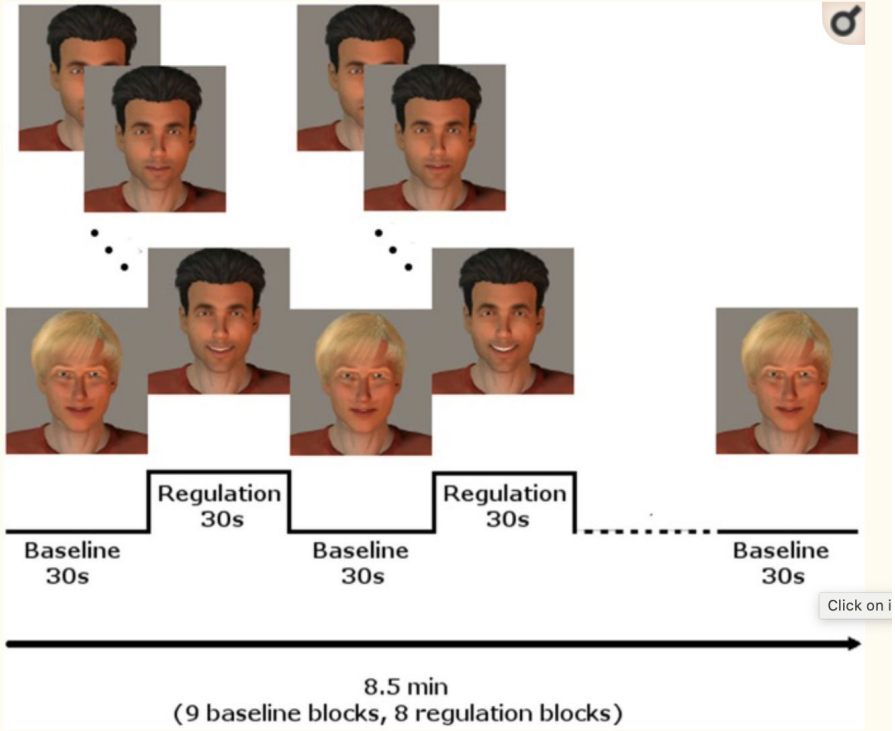
- Real time fMRI neurofeedback (Sulzer et al., 2013)
  - Seeks neurofeedback for a physiological target response and measurement of subject performance
  - Physiological target may be the average BOLD response in a chosen ROI OR a differential activity in two ROIs
  - Limitations:
    - Need to ensure it represents the underlying neural activity instead of physiological or movement artifact
    - Ex. eye movements could inflate rtfMRI training effects

- Advances in real time fMRI neurofeedback (Wantanbe et al., 2017)
  - Induce specific activation pattern in targeted region of brain
    - Using multivariate analysis
  - Modify neural connectivity between different brain regions

fMRI Neurofeedback (cont.)

- Cognitive and neural strategies during control of the anterior cingulate cortex by fMRI neurofeedback in patients with schizophrenia (Cordes et al., 2015)
    - 11 patients with schizophrenia, 11 healthy controls
    - NF training to enable them to control their ACC over a period of 3 days, 3 sessions per day
    - NF tasks had subjects regulate the smiling intensity of face avatars
    - Subjects advised to use individualized mental strategy
    - fMRI NF training of ACC activity in patients with schizophrenia led to activation of the dorsal ACC subsection, whereas controls activated the rostral subsection
    - Caution: NF training with the aim to increase activity in the rostral ACC should consider to apply specific masks that do not cover the dorsal ACC.

fMRI Neurofeedback (cont.)



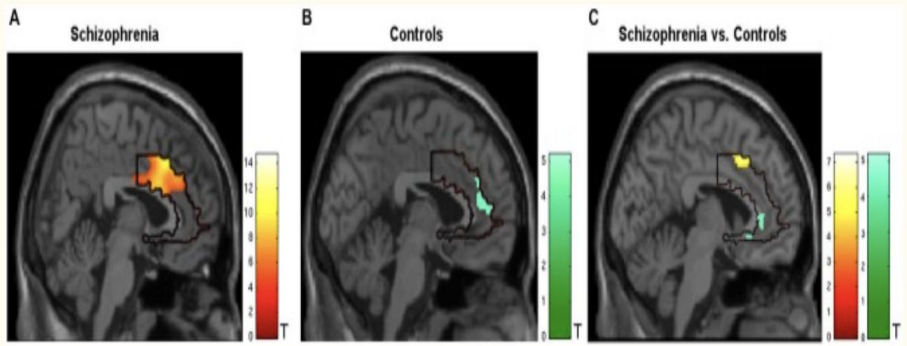


Figure 2

Activation during regulation of the ACC (outlined ROI). (A) Group of patients with schizophrenia ($n = 11$, warm colors), **(B)** matched controls ($n = 11$; cold colors), **(C)** patients > controls (warm) and controls > patients (cold). Across all training sessions and days, the patients activated the dorsal part of ACC whereas the control group yielded regulation at the rostral subdivision to change the signal from the allover ROI ($p < 0.05$, FWE- corrected).

(Cordes et al., 2015)

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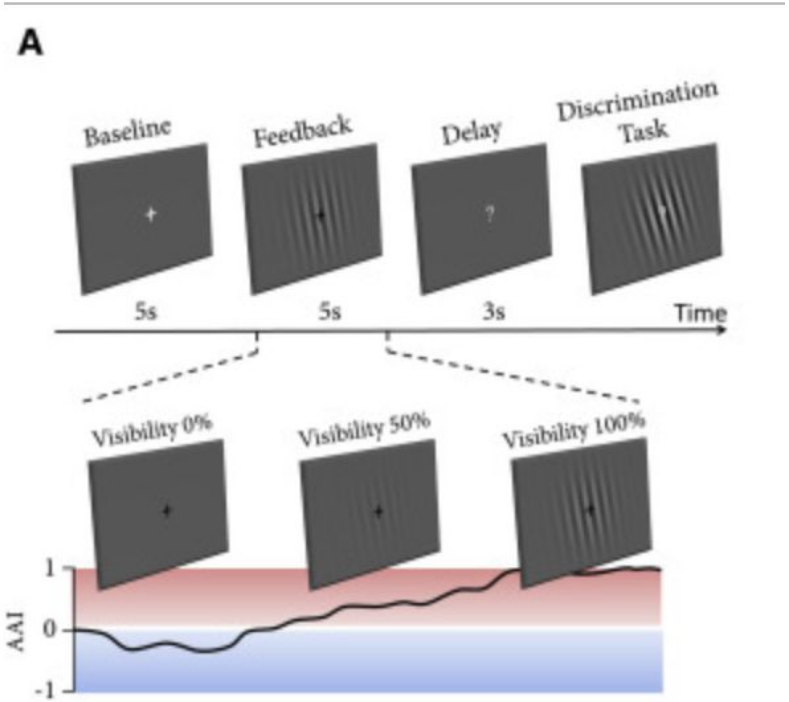
MEG Neurofeedback

- Alpha Synchrony and the Neurofeedback Control of Spatial Attention (Bagherzadeh et al., 2020)
  - Used MEG neurofeedback to show the causal relationship between alpha synchrony and spatial attention.
    - Influenced by a MEG study done by Okazaki et al. (2015) which also trained participants to modulate alpha hemispheric asymmetry.
  - 20 subjects trained to manipulate relative alpha power over the parietal cortex in the left versus right hemisphere.
    - Divided into 2 groups: LNT and RNT
  - 30 minute NF trials over 100 NF sessions
  - Subjects performed an orientation match-to-sample task with foveally presented gratings and instructed to try and increase the contrast.



MEG Neurofeedback (cont.)

- Alpha Synchrony and the Neurofeedback Control of Spatial Attention (Bagherzadeh et al., 2020)
  - Neurofeedback training successfully modulated hemispheric alpha asymmetry over the parietal cortex
    - In both the LNT and RNT groups in the desired direction
  - Found sustained modulation of spatial attention after NF
    - Posner cueing paradigm
  - Results support alpha synchrony playing a causal role in modulating attention and visual processing
  - Cautions: potential negative effects for healthy controls
    - Enhanced alpha associated with reduced sensory processing

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Current Ideas & Considerations

- Brain Region
  - Broad Region: Prefrontal Cortex
  - Specific Region: Anterior Cingulate Cortex, Amygdala, Inferior Frontal Gyrus
- Potential Tasks
  - EEG clinical tasks: driving/flying games, puzzles
  - Straightforward tasks: regulation of brain frequency
  - Simple tasks: keep a ball afloat, change a background color, regulating a thermometer
- Considerations
  - Implications with schizophrenia, depression, PTSD, phobias, etc.
  - Affecting healthy controls