Marie Curie Initial Training Networks (ITN)

Individualised Diagnostics and Rehabilitation of Attention (INDIREA)

Paul Dockree
Ian Robertson
Trinity College Dublin

TRINITY COLLEGE
Institute of Neuroscience
from molecules to mind

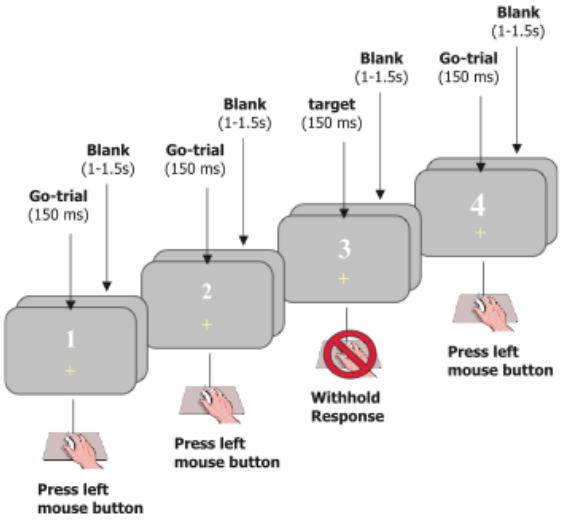
NEIL

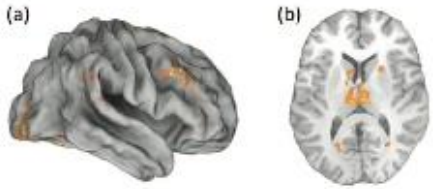
Overview

- Research in Trinity College Institute of Neuroscience (TCIN)
  - Performance monitoring and awareness
  - Transcranial direct current stimulation (tDCS)
  - Sustained attention -> TVA parameters
- How ESRs 11 and 12 can contribute the the rehabilitation aims of the INDIREA research program
  - tDCS protocols for selective improvements in attention and awareness
  - EEG biofeedback as a method for upregulating alertness

Awareness, brain injury and aging

- Experimental studies of in-the-moment or online awareness and self-awareness in daily life
- Brain injury patients show impaired awareness of errors in routine action (McAvinue, O'Keeffe, McMackin, & Robertson, 2005; O'Keeffe, Dockree, et al., 2007a; O'Keeffe, Dockree, & Robertson, 2004).

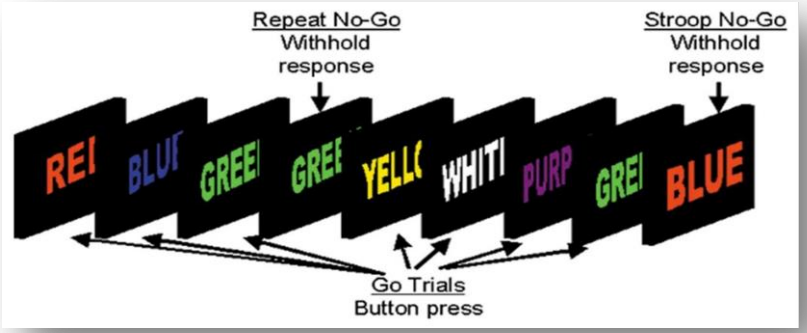




O'Connor C, Robertson IH, Levine B. The prosthetics of vigilant attention: random cuing cuts processing demands. Neuropsychology. 2011 Jul;25(4):535-43.

Error Awareness Task (EAT)

- Older adults have diminished awareness of errors in the laboratory and daily life (Harty, O'Connell, Hester, & Robertson, 2012).
- Adaptively modified the difficulty of EAT to ensure comparable accuracy levels between young & old participants
- Older adults were aware of 25% fewer errors than younger adults
- Online error awareness correlated with self-other discrepancy questionnaires measures



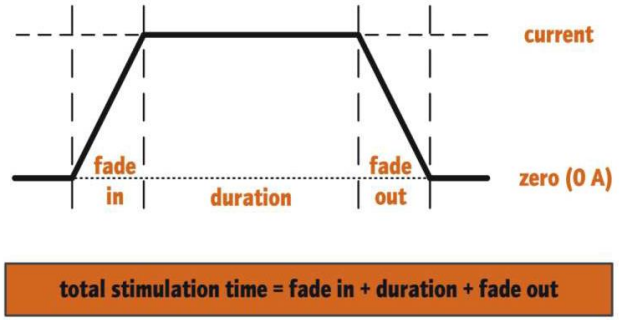
Harty, O'Connell, Hester, & Robertson, 2012 *Psychology & Aging*

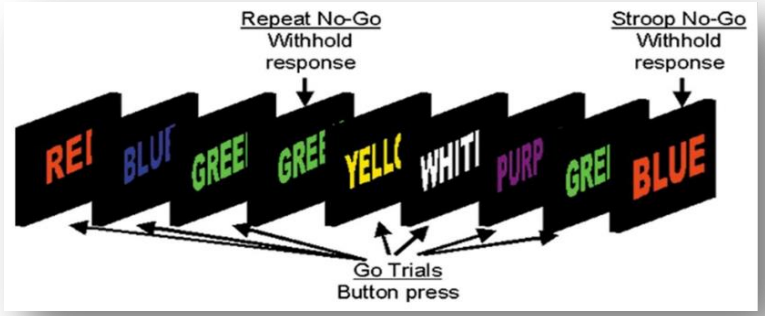
Online awareness and right prefrontal cortex

- Ability to signal errors is compromised in patients with right lateralized lesions (Hoerold, Pender, & Robertson, 2013)
- Down regulation of right DLPFC in patients with AD (Antoine et al, 2004) and FTD (Mendez & Shapira, 2005)
- Right PFC linked to metacogntive awareness of perceptual decision (Fleming, Huijgen & Dolan, 2012).
- transcranial Direct Current Stimulation (tDCS) to right prefrontal and error awareness in healthy elderly (Harty, Robertson, Hester & O'Connell, 2012)

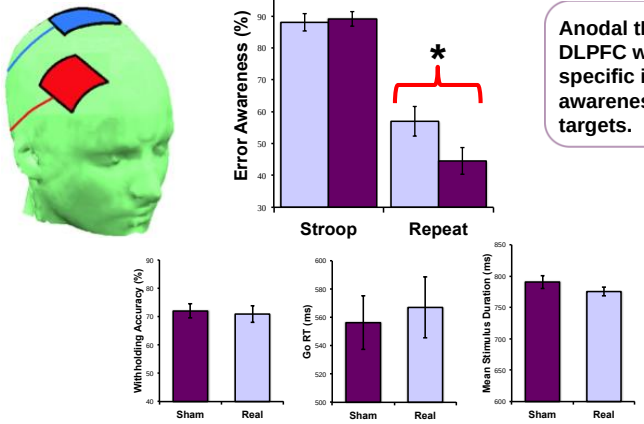
transcranial Direct Current Stimulation (tDCS)

- tDCS applies a weak direct current (1-2 mA) at the scalp which induces cortical excitability (Nitsche & Paulus, 2000)
- Polarity of current has different effects:
  - Anodal – increases neural firing rates
  - Cathodal – decreases firing rates
- Ramping period equated in real and sham stimulation conditions
- Real and sham Stimulation - 6 days apart



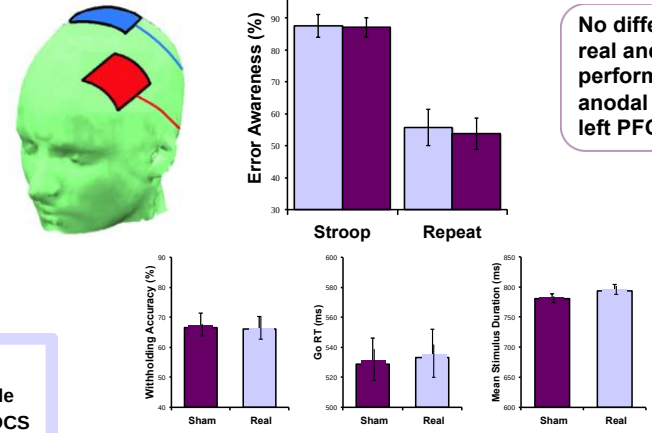


1) Effects of Anodal tDCS to the Right DLPFC on EAT Performance



Anodal tDCS applied to right DLPFC was associated with a specific improvement in awareness for Repeat targets.

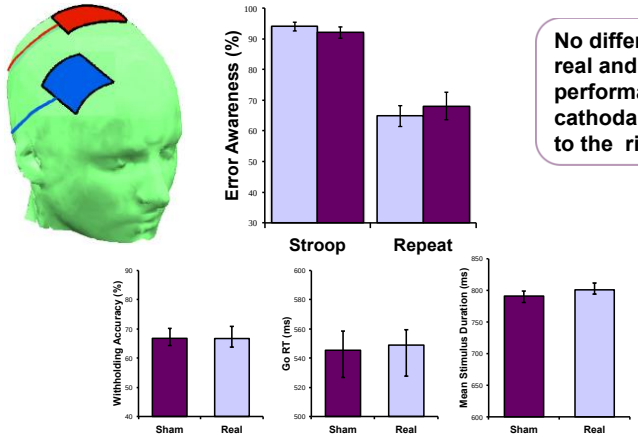
2) Effects of Anodal tDCS to the Left DLPFC on EAT Performance



No differences between real and sham for any EAT performance indices when anodal tDCS was applied to left PFC.

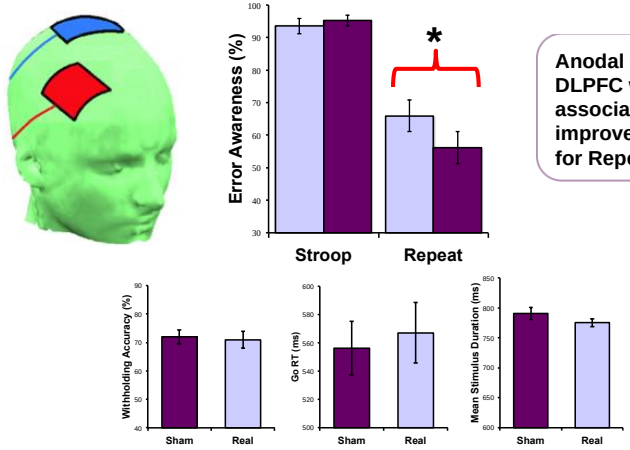
Anode
Cathode
Real tDCS
Sham tDCS

3) Effects of Cathodal tDCS to the Right DLPFC on EAT Performance



No differences between real and sham for any EAT performance indices when cathodal tDCS was applied to the right PFC

4) Effects of Anodal tDCS to the Right DLPFC on EAT Performance (Replication

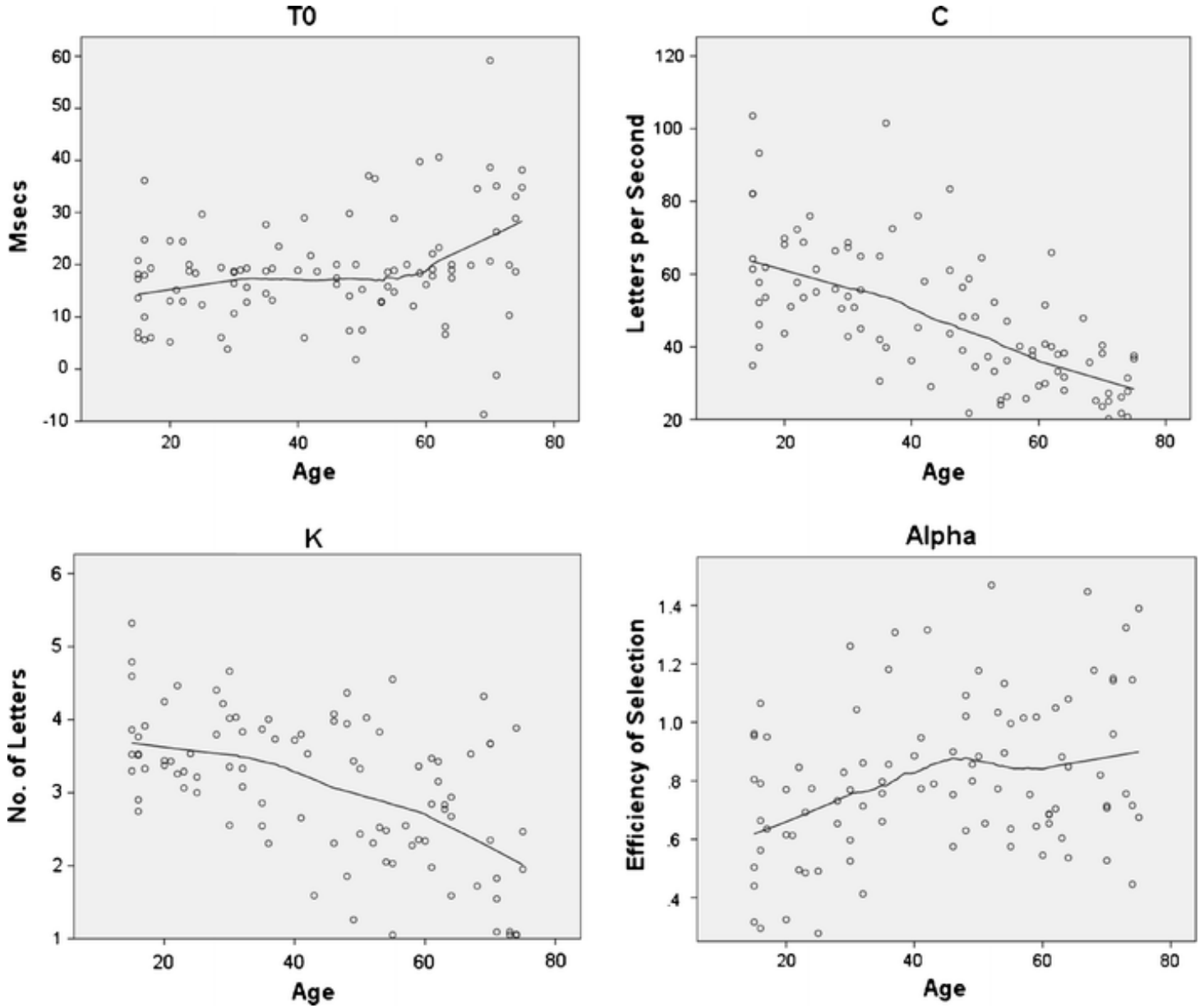


Anodal tDCS applied to right DLPFC was once again associated with a specific improvement in awareness for Repeat targets.

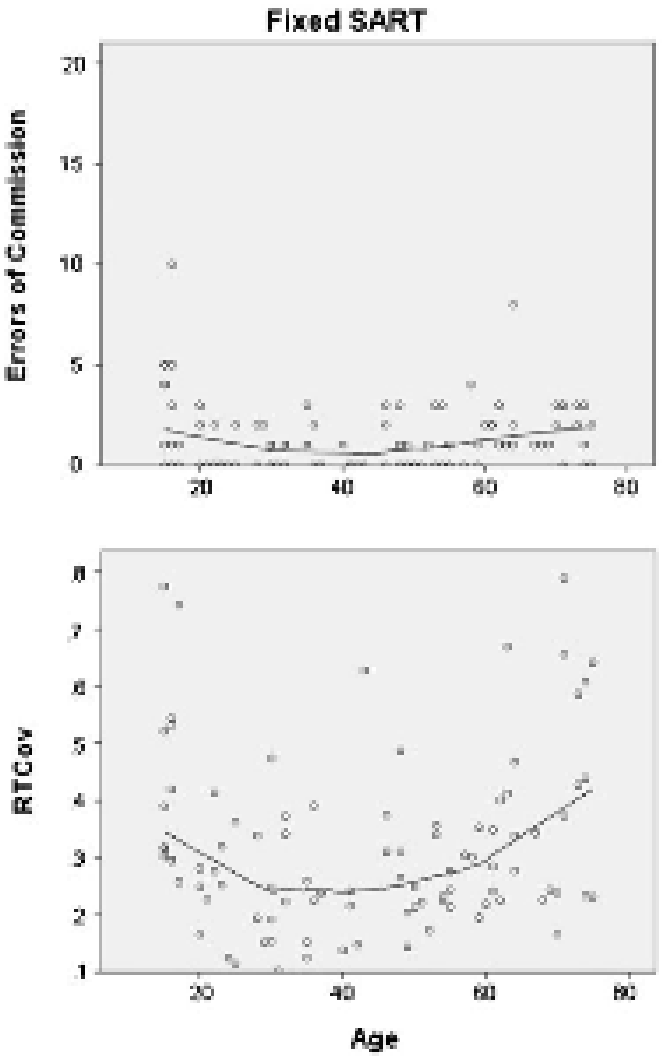
Awareness and Sustained Attention

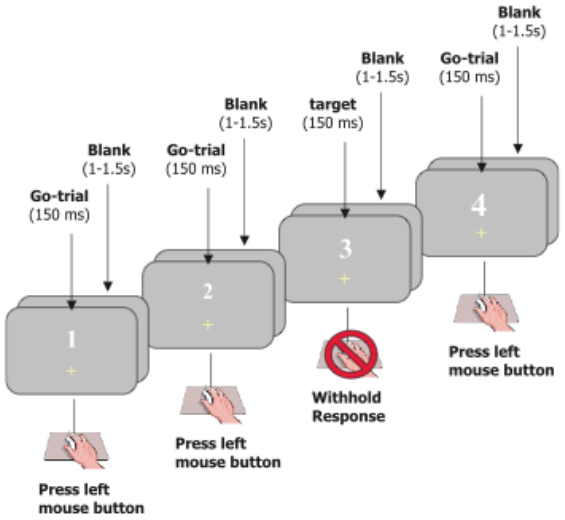
- Online error awareness and sustained attention capacity are reliably associated (Harty et al, 2012; Hoerold et al., 2008; O'Keeffe et al., 2007; McAvinue et al. 2005, Shalgi et al 2007)

- Impairments of sustained attention (propensity for lapses) may therefore be fundamental to emerging awareness deficits (Robertson, 2010; Dockree, O'Connell & Robertson, in press)



McAvinue LP, Habekost T, Johnson KA, Kyllingsbæk S, Vangkilde S, Bundesen C, Robertson IH. Sustained attention, attentional selectivity, and attentional capacity across the lifespan. Atten Percept Psychophys. 2012 Nov;74(8):1570-82.





McAvinue LP, Habekost T, Johnson KA, Kyllingsbæk S, Vangkilde S, Bundesen C, Robertson IH. Sustained attention, attentional selectivity, and attentional capacity across the lifespan. Atten Percept Psychophys. 2012 Nov;74(8):1570-82.

TABLE 4
Component matrix for TVA parameters and errors of commission on the fixed and random SARTs

Variables	*Component 1*	*Component 2*	*Component 3*
K	**.854**	.184	−.183
C	**.839**	−.204	.135
Fixed ERCs	.056	**.751**	.146
Random ERCs	−.080	**.729**	−.196
t_0	−.179	.181	**.756**
α	.120	−.201	**.651**

McAvinue LP, Habekost T, Johnson KA, Kyllingsbæk S, Vangkilde S, Bundesen C, Robertson IH. Sustained attention, attentional selectivity, and attentional capacity across the lifespan. Atten Percept Psychophys. 2012 Nov;74(8):1570-82.

OVERALL AIMS OF INDIREA

- AIM 1: to enhance the neuropsychological diagnosis of attentional disorders by linking clinical measures to detailed cognitive models and their associated neural biomarkers
- AIM 2: to use advanced neuropsychological measures of attention (AIM 1) to design and evaluate individualised rehabilitation for attentional dysfunctions
- AIM 3: to provide a new cohort of PhD students with inter-disciplinary scientific and technological skills specifically linked to generating commercial outputs (e.g., in new diagnostic tests, in biofeedback)

OVERALL AIMS OF INDIREA

- AIM 1: to enhance the neuropsychological diagnosis of attentional disorders by linking clinical measures to detailed cognitive models and their associated neural biomarkers

- **AIM 2: to use advanced neuropsychological measures of attention (AIM 1) to design and evaluate individualised rehabilitation for attentional dysfunctions**

- AIM 3: to provide a new cohort of PhD students with inter-disciplinary scientific and technological skills specifically linked to generating commercial outputs (e.g., in new diagnostic tests, in biofeedback)

ESRs 11 and 12 (WP 4 – Rehabilitation)

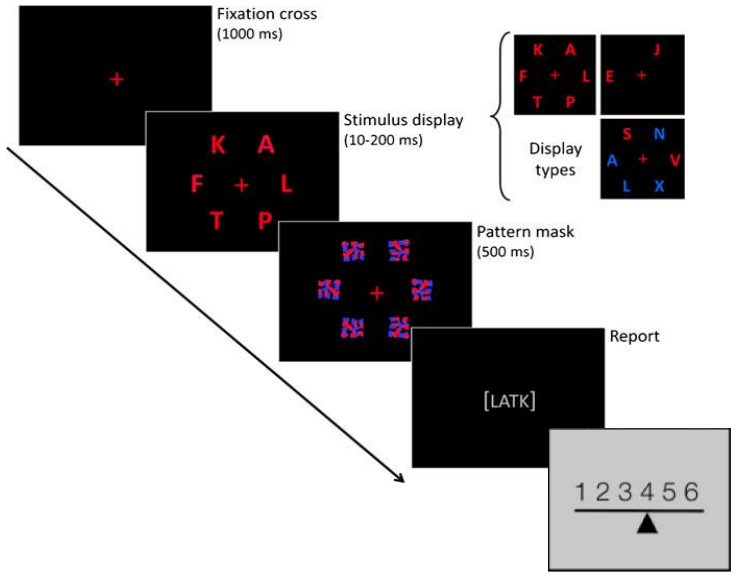
- To selectively enhance different facets of attention and awareness using non-invasive brain stimulation
- To enhance sustained attention using EEG feedback as a means to drive improvements in TVA parameters and awareness.

Enhancing attention using tDCS

- General Plan:
  - Cross-over designs in healthy older subjects
    - specific TVA parameters to be targeted
    - Event Related Potentials & oscillatory signals linked to TVA parameters
  - Randomised controlled experimental design with low memory performing older adults
    - subjects randomly assigned to either a real or sham stimulation group
    - BCoS-derived tests (WP1) as pre & post measures

Right prefrontal tDCS

- Right prefrontal transcranial direct current stimulation (tDCS) (Anodal and Cathodal)
  - Improve selection *α* (Bublak et al 2005)
  - Improve processing speed *C* (Habekost & Rostrup 2007: Matthias et al 2010)
  - Improvements in processing speed linked to visual N1 modulation (Wiegand et al 2013)
  - Enhance meta-cognition (Harty et al)



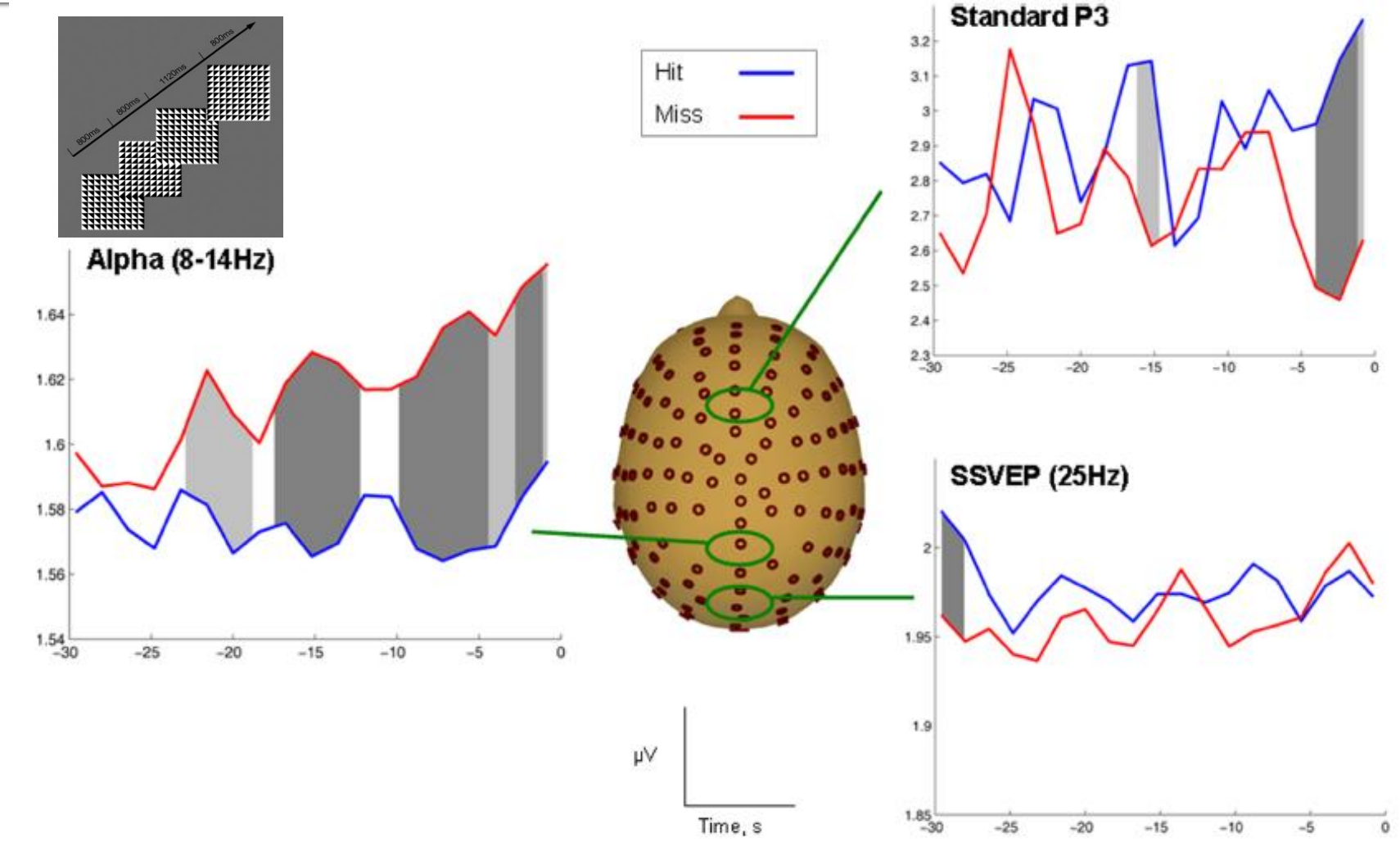
Left prefrontal tDCS

- Left prefrontal transcranial direct current stimulation (tDCS) (Anodal and Cathodal)
  - Increase Visual short-term memory capacity –***K***
  - Enhanced sustained contralateral delay activity over visual areas (Wiegand et al 2013)

Right posterior parietal tDCS

- Right posterior parietal transcranial direct current stimulation (tDCS) (Anodal and Cathodal)
  - balance of w_{index} across hemifields (Bublak et al 2005)
  - Improve selection α (Moos et al 2012)
  - Oscillatory alpha as an active attentional suppression mechanism (Kelly et al 2006; Foxe & Synder, 2011)

Predicting lapses of attention across multiple time-scales



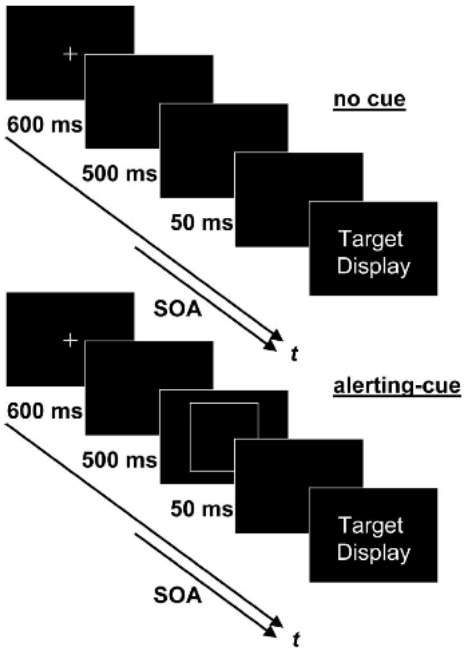
O'Connell RG, Dockree PM, Robertson IH, Bellgrove MA, Foxe JJ, Kelly SP. Uncovering the neural signature of lapsing attention: electrophysiological signals predict errors up to 20 s before they occur. J Neurosci. 2009 Jul

Enhancing attention using EEG alpha feedback

- General plan:
  - Cross-over design in young and healthy older adults
    - Pre-stimulus alerting cues: alpha contingent feedback vs. random alerts
    - Examine differential effects on TVA parameters.
  - Randomised controlled experimental design with low memory performing older adults
    - subjects randomly assigned to either an alpha-contingent or random alert group
    - BCoS-derived tests (WP1) as pre & post measures

Alertness cues and the TVA

- Alertness cues affect both spatial and non-spatial parameters of the TVA (Matthias et al 2010)



- A feedback cue to be provided in the pre-target interval when in the cumulative temporal evolution of alpha exceeds pre-fixation levels.
- Extend to low memory performing older adults as randomised controlled experimental design.

Summary

- ESRs will individualise tDCS neurorehabilitation protocols for different aspects of attention and awareness
- ESRs will examine the mechanism of improvement using simultaneous tDCS-EEG measurements
- ESRs will utilise EEG signals through biofeedback to optimise regulation of attention and awareness