PERFORMANCE ENHANCEMENT IN ELITE ATHLETES

Quantitative Electroencephalogram, Event-Related Potential and eLoreta Source Localisation Identify EEG Biomarkers of Visuo-Spatial Processing and Motor-Preparation in Elite Table Tennis Players

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Overview

1. **Problem:** Current Performance Enhancement tools for psychology are limited.

2. **What I do:** Quantitative EEG (QEEG) brain-mapping and Neurofeedback (NFB) training.

3. **How 'what I do (2)' addresses 'the problem (1)'.** Example from my research of application process.

1. Problem

- Current psychological performance enhancement tools for both the *clinical* population and the *elite* population rely mainly on:

1. Medication
2. Talking therapies

Medication

- Clinical population: e.g. ADHD, anxiety, depression… the 'go-to' solution due to lack of alternative in some cases.

- Elite population: Aim to push physical limits in order to compete harder and train more

Possible negative side effects and only temporary benefits

Talking therapies

- Clinical: CBT, Mindfulness – great, but sensory processing deficits in the brain, e.g. Autism, ADHD???

- Elite : e.g. sports psychology – great, but mainly limited to conscious control of emotion/anxiety, motivation, confidence. Visual processing speed? Spatial attention?

"TOUGHEN UP!!!" "FIGHT HARDER!!!"

Opportunity

- Room for Neuropsychological intervention in Peak Performance training that adds to existing methods:

1. Medication-free.
2. Assists automatic and early psychological processes, e.g. visual-spatial attention.
3. Objectively measured.
4. Stimulates long-term brain change.
5. Already being successfully applied in the clinical population.

2. What I do:

Apply brain-training performance enhancement tools for:

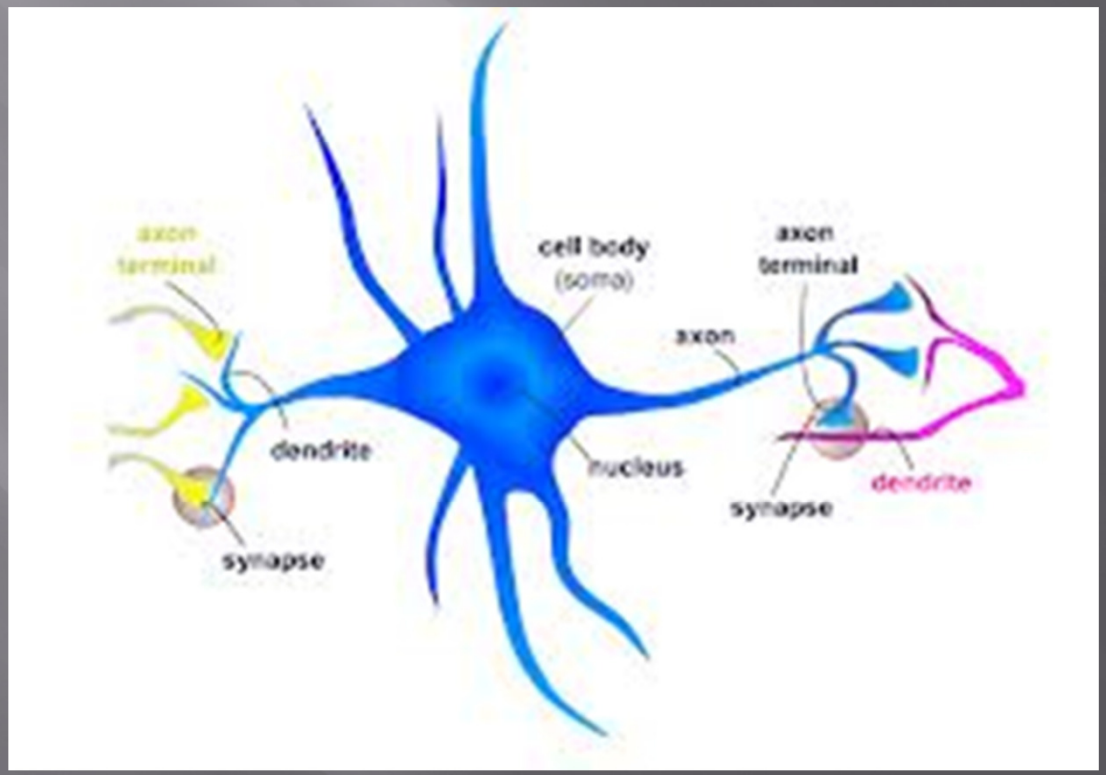
1. Clinical work: ASD, ADHD, PTSD, Anxiety, Depression – exists already…

2. PhD research: Sport population

How…?

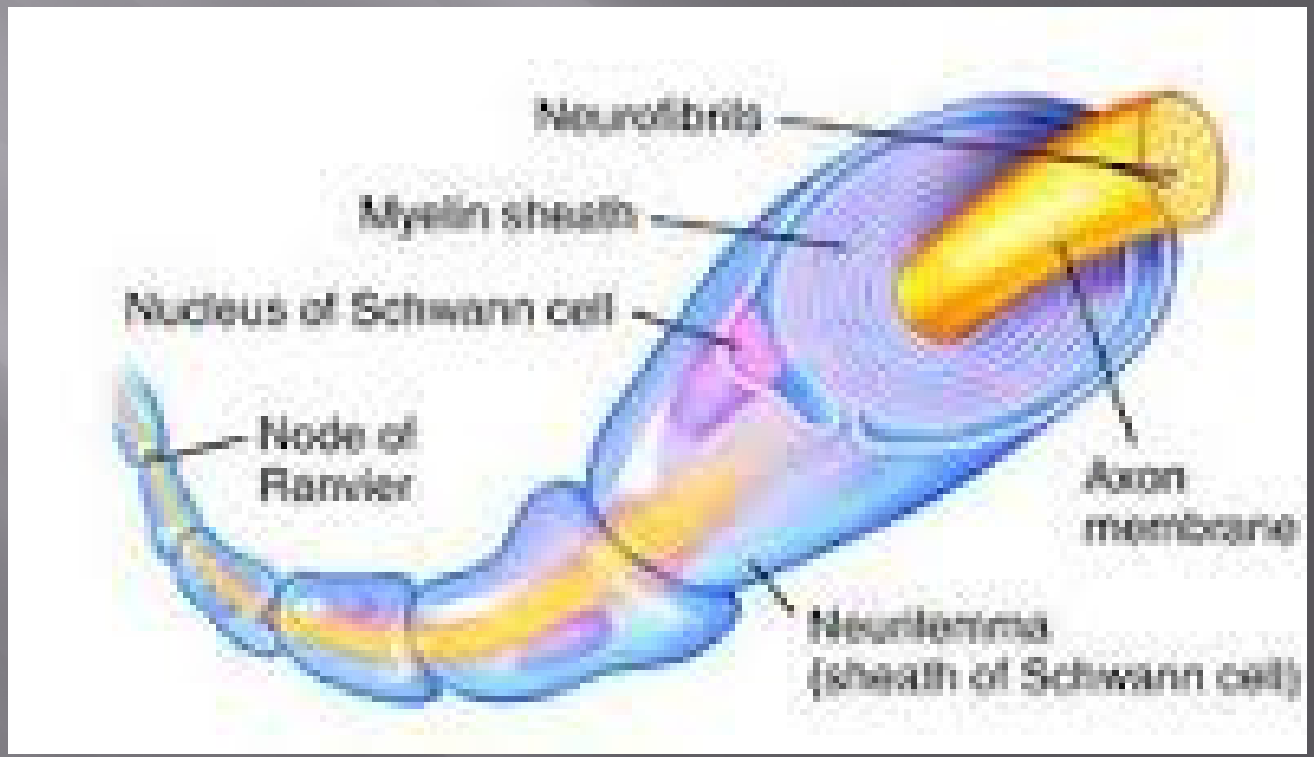
Brain Change – Neuroplasticity

1. Neuronal growth, new synaptic/dendritic connections
2. Neuronal pruning



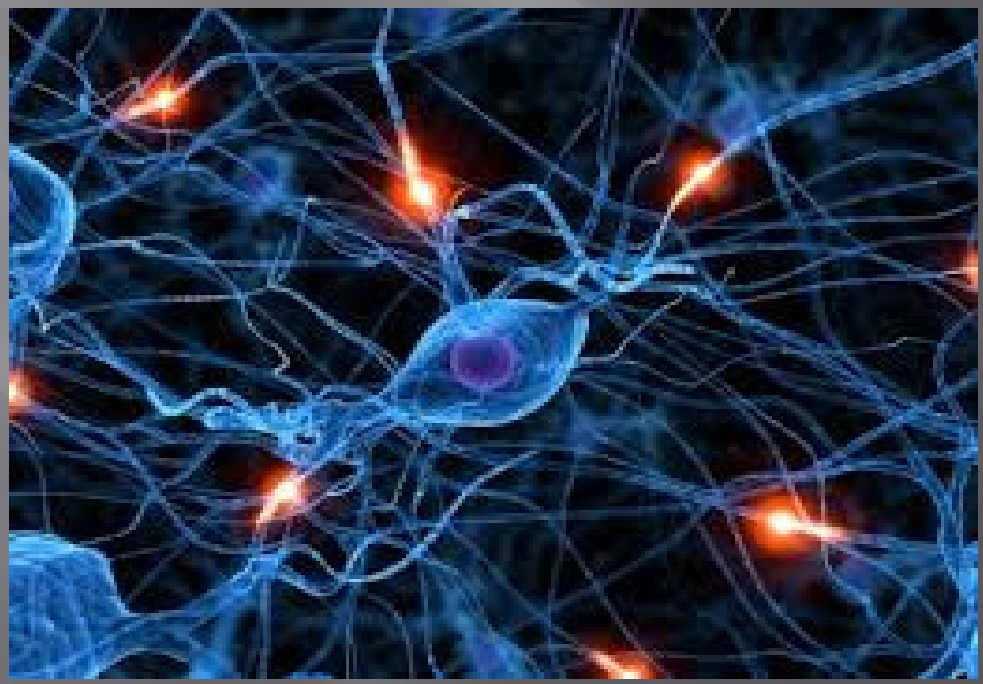
Neuroplasticity

3. Myelination
4. Brain Derived Neurotropic Factor (BDNF) during 'Heightened Attention' e.g. Novel situation



Neuroplasticity

- Learning (e.g. new skills)
- More efficient brain function (e.g. memory retrieval)
- Brain repair (e.g. after stroke/TBI)



Can we assist Neuroplasticity?

1. Understand how a unique brain is functioning through assessments (**Quantitative EEG**, fMRI, DTI, etc.)

2. Stimulate Neuroplasticity in the desired location through neuromodulation techniques (**Neurofeedback**, TMS, tDCS, etc.)

Quantitative EEG Brain Mapping

Electroencephalography (EEG)

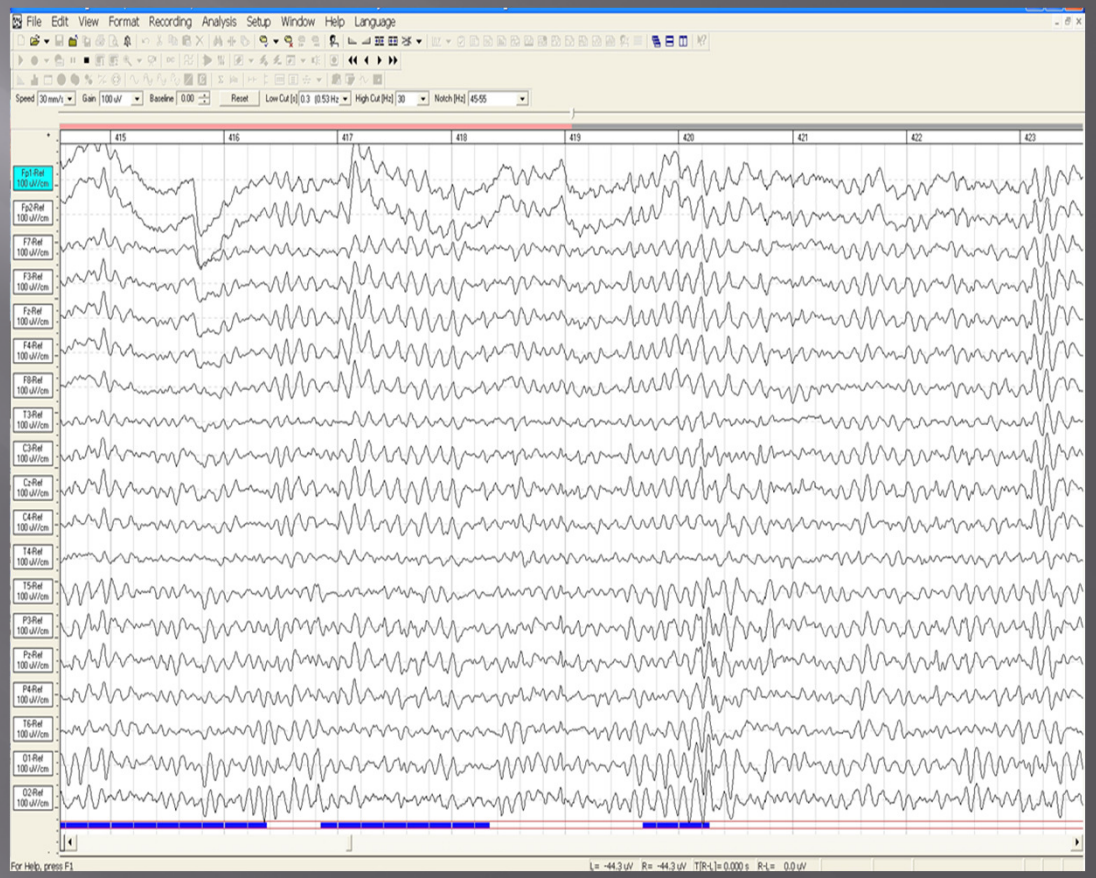
Pyramidal Neurons:

1. **Create an electrical current**

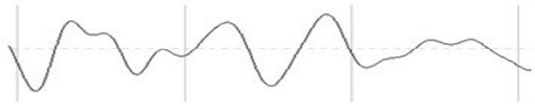
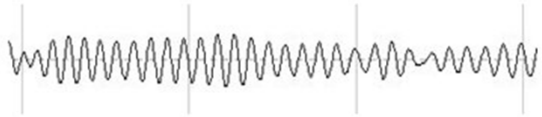
2. **Fire synchronously**

3. **Are radially orientated**

Recording of electrical activity on the scalp using electrodes over multiple sites, usually 19 channels.

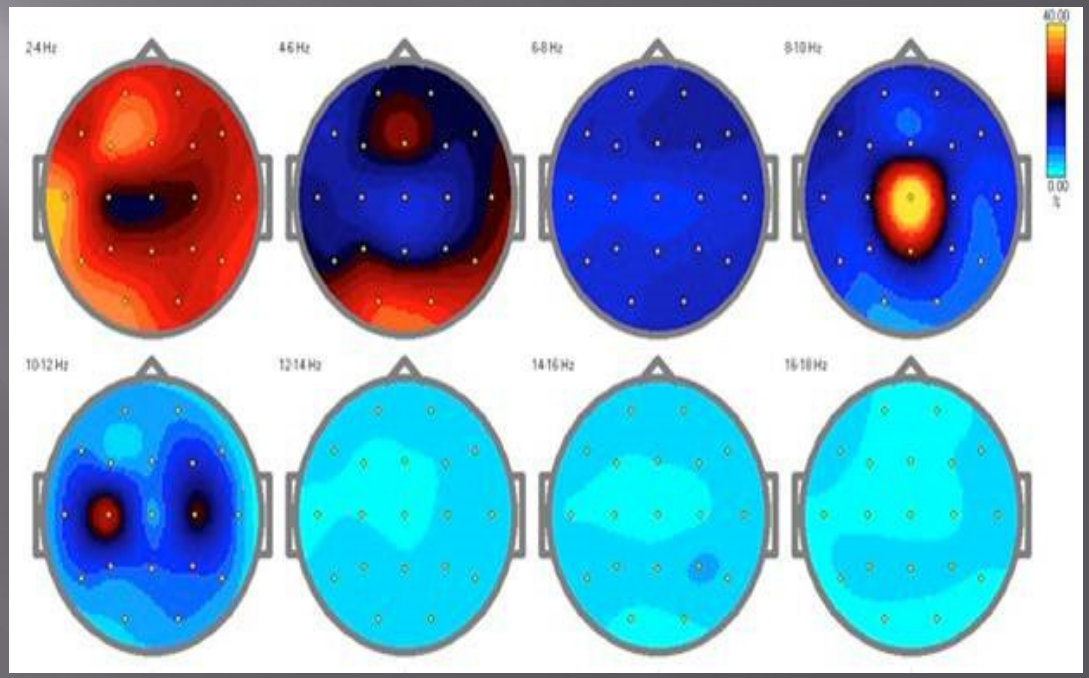


Different EEG frequencies are associated with different brain states

Frequency Band Name	Frequency Bandwidth	State Associated with Bandwidth	Example of Filtered Bandwidth
Raw EEG	0-45 Hz	Awake	
Delta	0.5-3.5 Hz	Deep Sleep	
Theta	4-7.5 Hz	Drowsy	
Alpha	8-12 Hz	Relaxed	
Beta	13-35 Hz	Engaged	

Quantitative EEG Brain Mapping

1. This EEG is then averaged over a time period – giving the "quantitative" part of QEEG displayed on "topographic maps".



2. Compared to Who?

Elite athletes?
Normal population?

QEEG Benefits

1. Cheap, portable and captures millisecond timing of information processing (unlike fMRI).

2. Identification of EEG 'biomarkers' within a population, used for **talent identification** in a particular sport, or **diagnosis** of a particular clinical disorder.

3. Guides treatment through either medication (to medicate or not, e.g. endophenotypes of ADHD) or Neuromodulation techniques (area of the brain to stimulate Neuroplastic change)

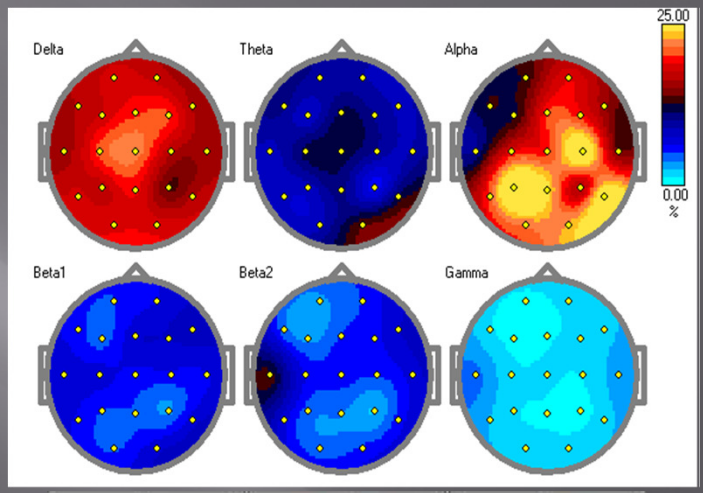
What is Neurofeedback theoretically?

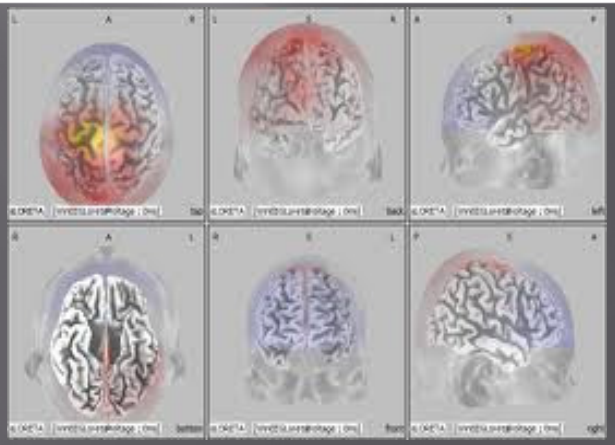
Operant Conditioning

1. A learning process in which the likelihood of a specific behaviour is increased or decreased through positive or negative reinforcement each time the behaviour is exhibited, so that the subject comes to associate the pleasure or displeasure of the reinforcement with the behaviour and thus increases or decreases the repetition of this behaviour.
2. Stimulating Neuroplasticity in the desired cortical location – neurons that fire together, wire together.

Neurofeedback Training

1. QEEG and source localisation analysis helps identify regions and frequencies to be trained – guiding NFB protocol





2. Let's see how it's done

NEUROFEEDBACK

1. NFB uses sensors on particular sites to relay, in real time, EEG information back to the client in the form of, e.g. graphs, computer games, video jamming.

2. The client then receives reward in both audio and visual cues, when certain criteria are fulfilled.

3. Through operant conditioning, the client learns to up- or down-regulate their EEG within specific neural circuitry and stimulate neuroplasticity.

How does NFB work practically?

- Client goal (explanation of game)
- Feedback modality (game, video jamming, bar graph)
- 20-40 x 30 min sessions using scalp electrodes, or 10-15 sessions for 3D source localisation ‘Loreta NFB’.
- 1-2 electrodes on scalp using gel, or Loreta NFB using MNI coordinates generated by a full 19 channel cap (electrode placement 2-10 mins).

3. How what I do addresses our problem

- Our research gives an example of how QEEG, EEG source localisation and NFB are applied to increase psychological performance in new fields

- But first… what is peak performance?

Psychological Skills in Sport

Table tennis:

- up to 110 km/h
- spins of up to 150 revolutions per second at an average of 120 rps

The Flow experience

"I don't think I'll be able to properly describe what occurred on 25 September 2000. I'm intrigued by the fact that I didn't hear the crowd – didn't hear anything in the lead up to the race. One neurologist said I had simply trained myself to block out peripheral things so well that it had become an automatic reaction. I'd adjusted my awareness inside my mind to focus on one thing – running the race."

Cathy Freeman, 400m Olympic gold medallist

Flow Research – Ideal Performance State

"When you enter flow, you don't activate more of your brain, but rather transfer energy to specific parts of the brain that assist in heightening your performance. When you experience flow, there is an energy transfer inside your brain. Essentially your pre-frontal cortex shuts down, allowing you to access your unconscious processing system, which is a much quicker processor."

Steven Kotler– Co-Founder & Head of Research at the Flow Genome Project

Archery/Marksmen, Golf–Putting

- Archery/Marksmen: Left hemisphere temporo-parietal–motor cortex alpha (8-12Hz) increase in 3 second pre-shot period–(e.g. Hatfield, 2004).

- Golf-Putt: Event-related alpha (10-12Hz) desynchronisation (decrease in power) over Cz-Fz and C4 (right sensorimotor cortex) correlated with successful golf putts.

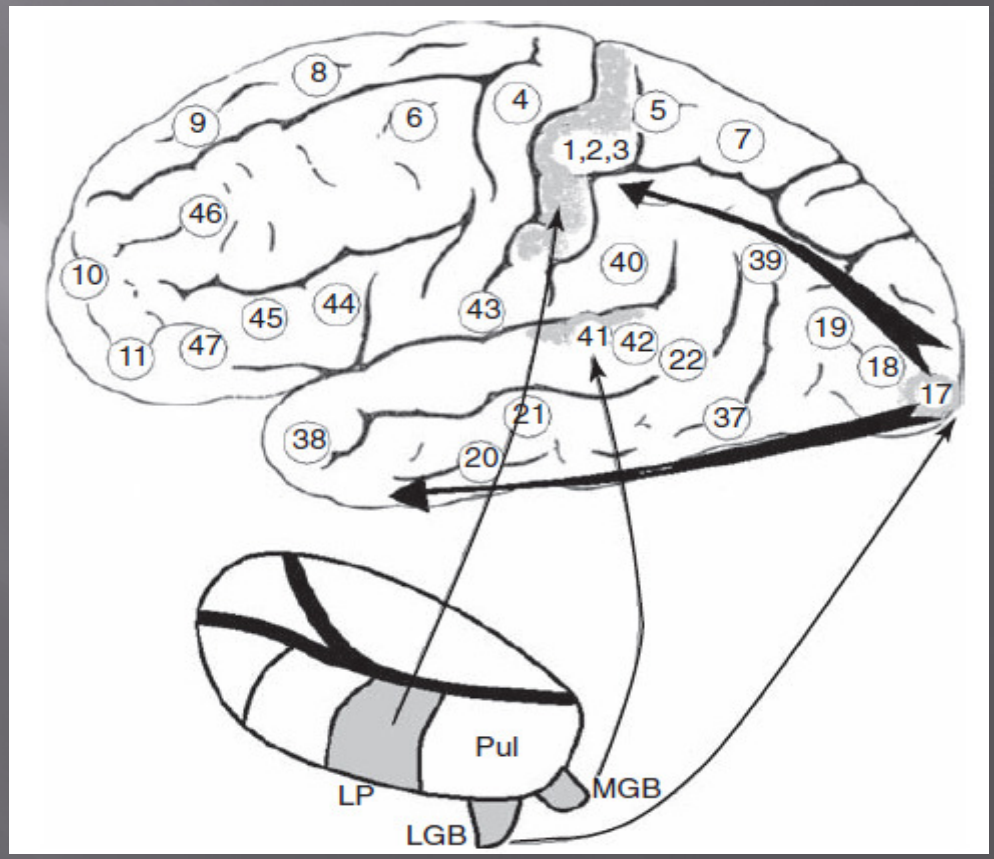
Identification of EEG Biomarkers of Visuo-Spatial Processing and Motor-Preparation in Elite Table Tennis Players:

Aim

- The aim of this study was to identify EEG biomarkers of visuo-spatial processing and motor-preparation present in elite table tennis players when compared to an age and gender matched non-elite, but experienced, group of players.
- Assess whether this is related to the Flow experience and Peak Performance.
- Use NFB to increase neuroplasticity in identified neural circuitry and thus increase performance.

Dorsal Attention Network

- Identifies 'where' an object is in space.
- Important for motor response and action selection.
- Links relevant visual stimuli to guide motor-planning.



Dorsal and Ventral visual streams
Kropotov, 2009. QEEG, ERP & Neurotherapy

Method

QEEG analysis

- Table Tennis players, N=206, age 13-52.
- EO, EC, Video Task (VT)
- Visual-spatial Go-Nogo tasks (2x10mins)

Neurofeedback training

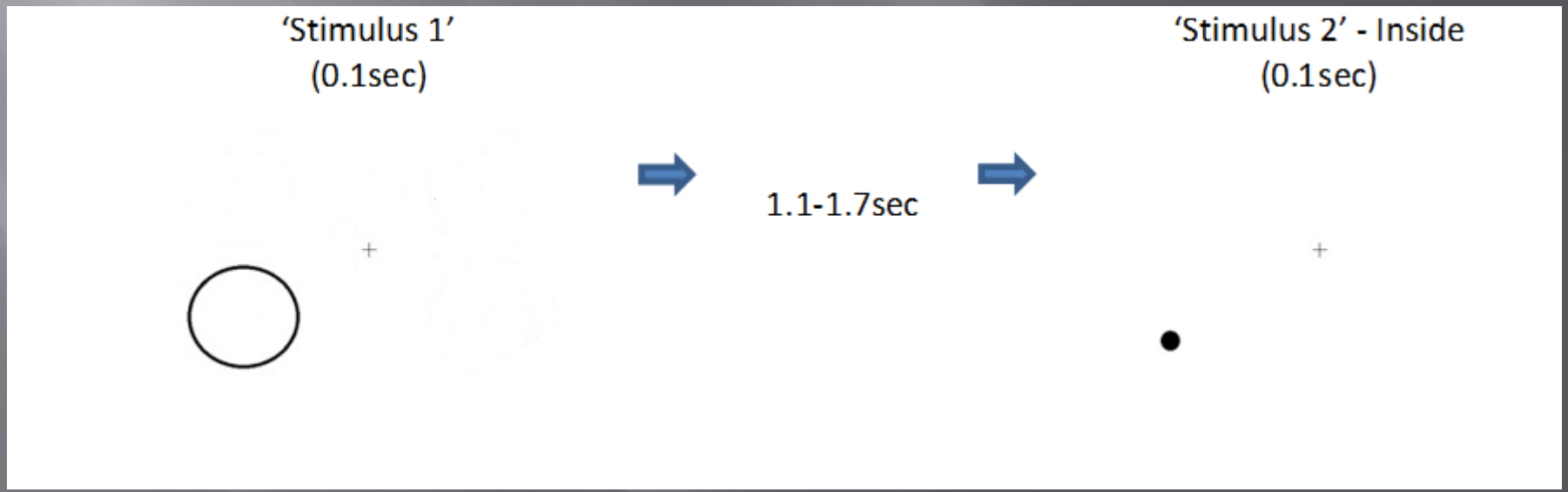
- 12 Nationally-ranked European table tennis players at a training camp in Denmark 2013
- 13 Polish junior players at a training camp 2014

Video Task

- Eyes Closed – Player sits calmly with eyes closed
- Eyes Open – Player sits calmly with eyes open looking at a fixation cross on the computer screen
- Table tennis video task – Player watches a video of table tennis points played from the players' perspective – instructed to imagine playing against this player

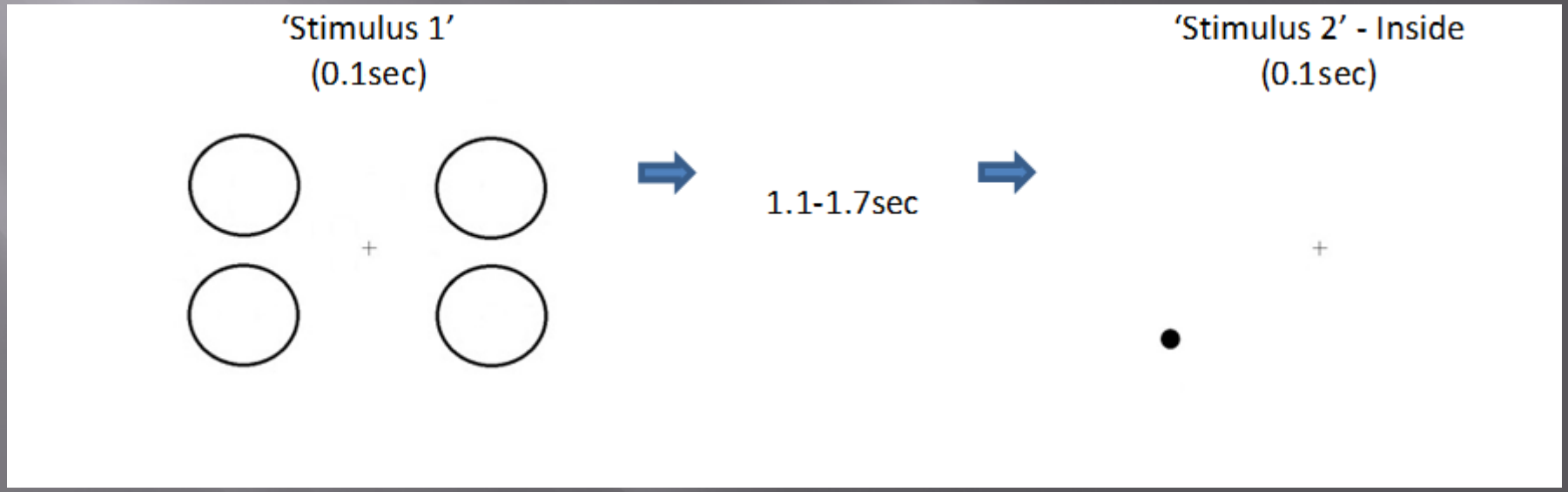
Dorsal Attention Network Task (1)

Go/NoGo 1/4 circles – Players' task was to click the mouse as quickly and as accurately as possible if he/she determined that the 'stimulus 2 dot' could be placed within where the 'stimulus 1 circle' had been

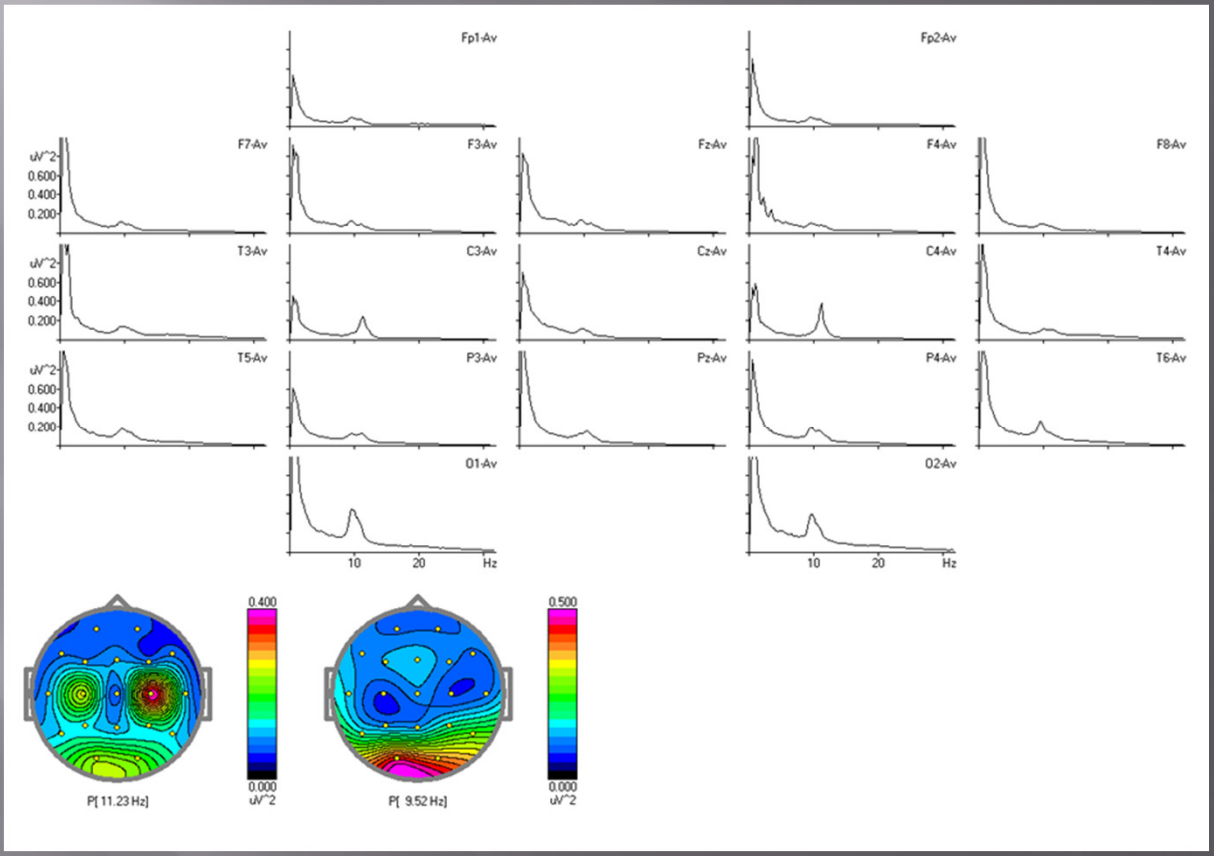


Dorsal Attention Network Task(2)

Stimulus 2 appeared either 1.1, 1.3. 1.5 or 1.7 seconds after stimulus 1. There were 96 'Go' trials (inside circle - click mouse) and 96 'NoGo' trials (outside circle - don't click mouse). Duration = 10 mins.

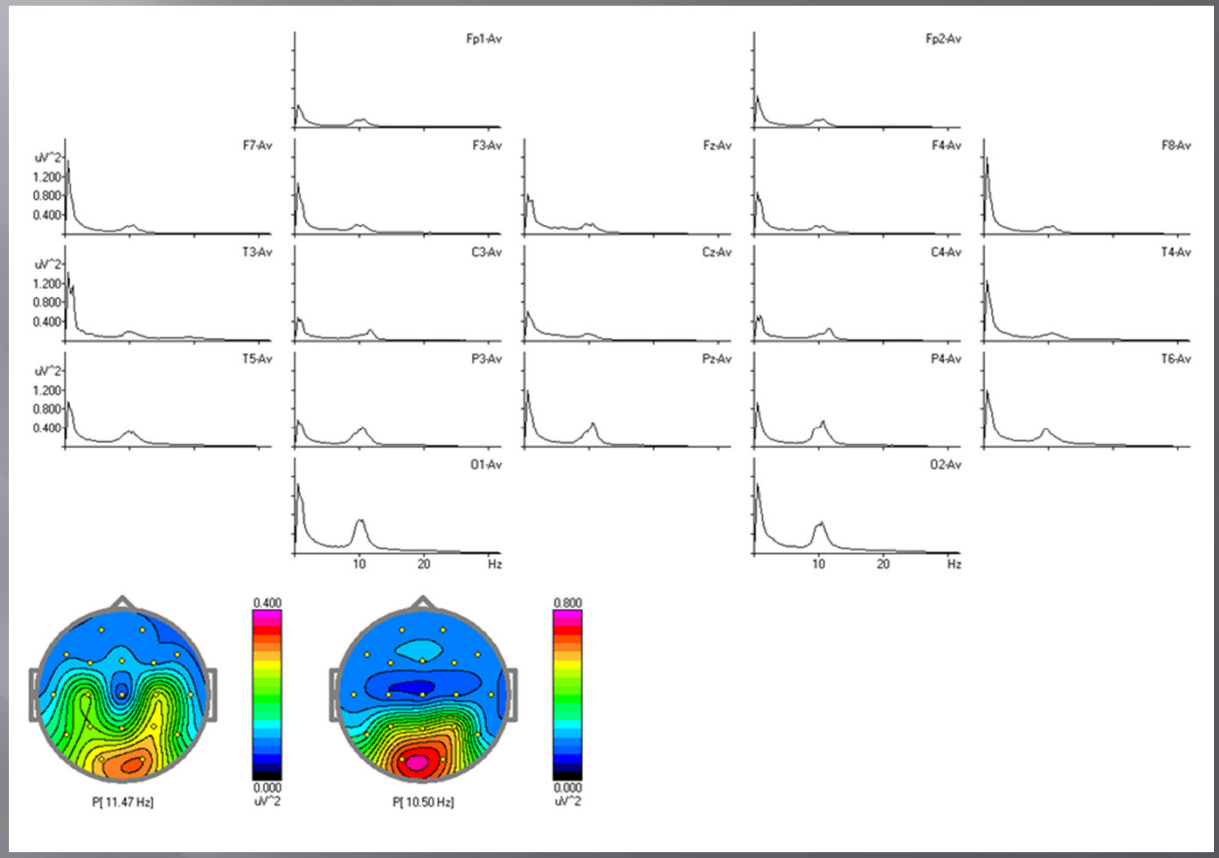


Results – Elite (Video Task)



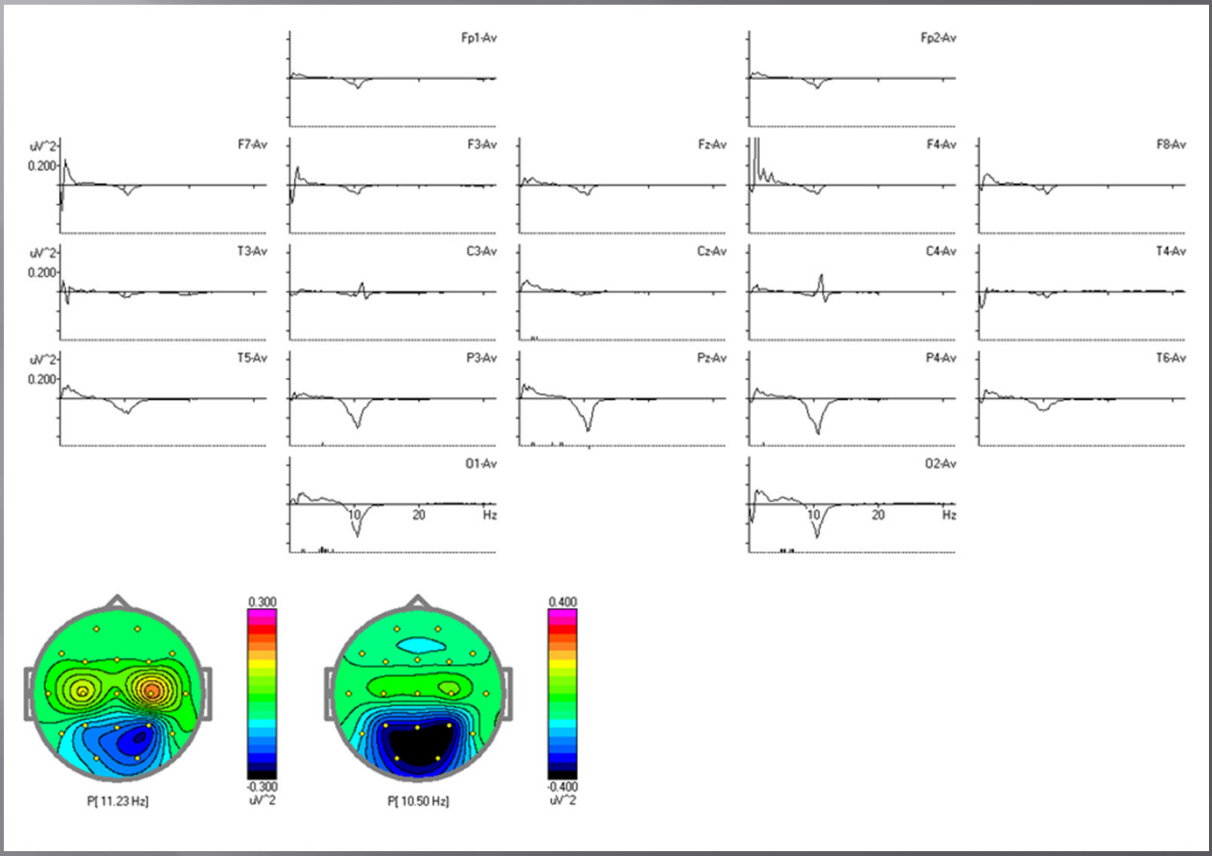
C4 peak = 0.379mV² at 11.23Hz

Results – Elite (EO)



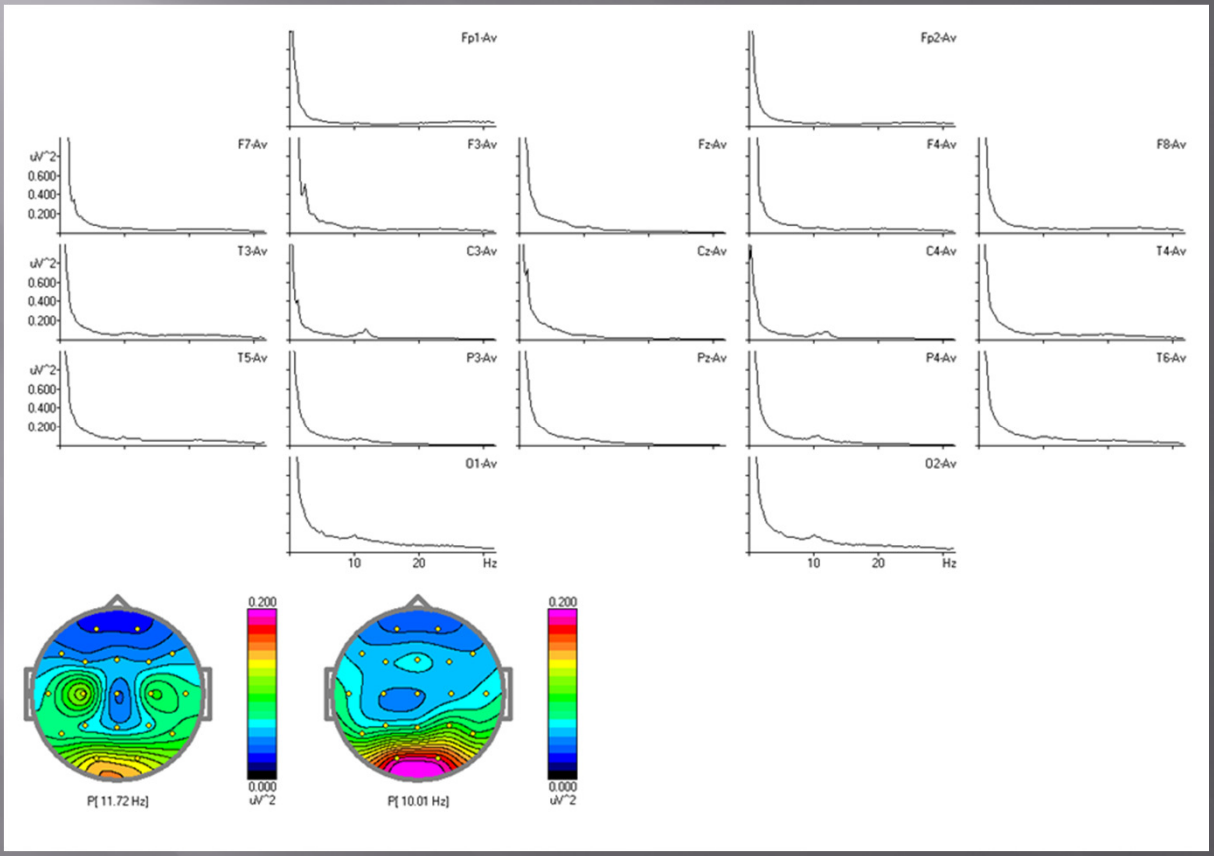
C4 peak = 0.249mV^2 at 11.47Hz

Results – Elite (VT–EO)



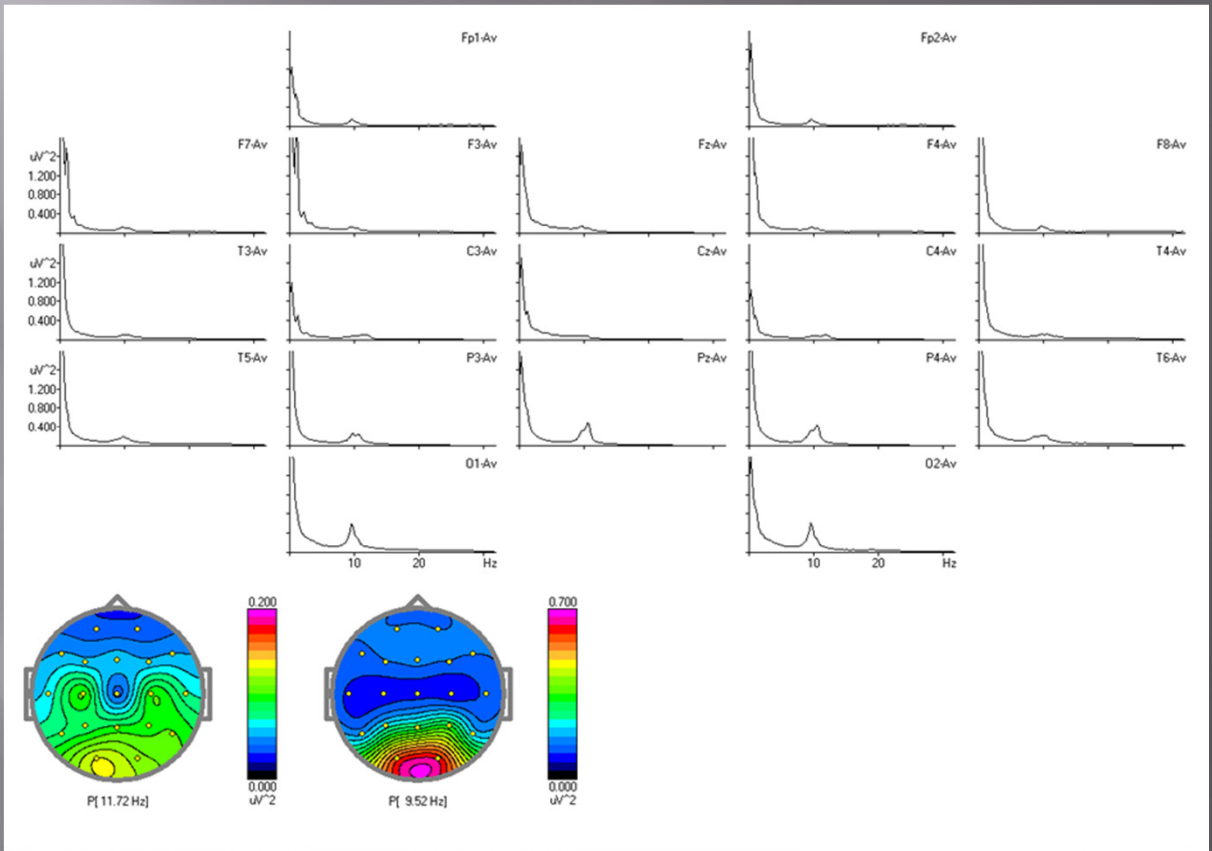
C4 peak = 0.176mV² at 11.23Hz

Results – Amateur (VT)



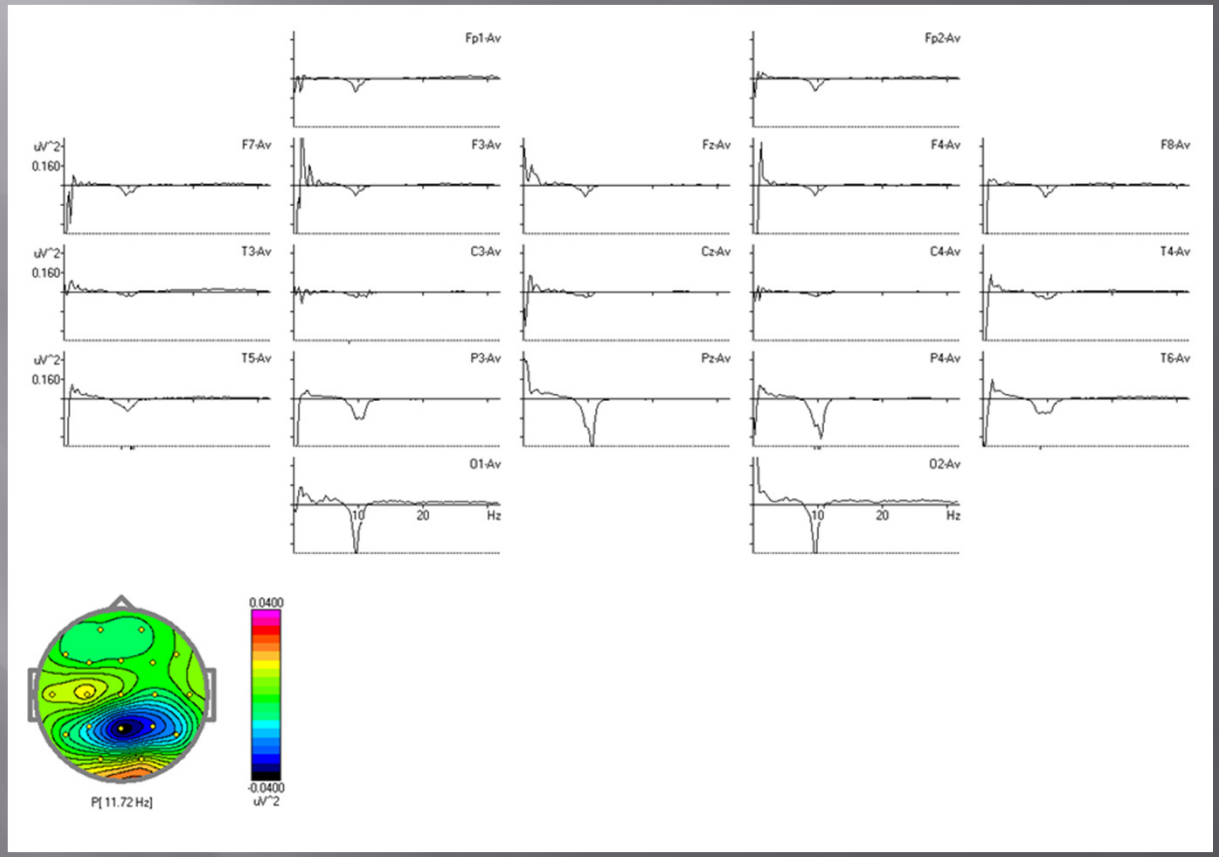
C4 peak = 0.090mV² at 11.72Hz

Results – Amateur (EO)



C4 peak = 0.098mV² at 11.72Hz

Results – Amateur (VT–EO)



C4 = -0.008mV^2 at 11.72Hz

Elite (VT) eLoreta

eLoreta analysis: max density at right BA6 (supplementary motor cortex) and BA13 (insula)

DAN1/4 ERP Tasks

Correlations

		Ranking	DAN1 Go Reaction Time	DAN4 Go Reaction Time
Ranking	Pearson Correlation	1	.354**	.392**
	Sig. (2-tailed)		.009	.003
	N	54	54	54
DAN1 Go Reaction Time	Pearson Correlation	.354**	1	.744**
	Sig. (2-tailed)	.009		.000
	N	54	72	72
DAN4 Go Reaction Time	Pearson Correlation	.392**	.744**	1
	Sig. (2-tailed)	.003	.000	
	N	54	72	72

**. Correlation is significant at the 0.01 level (2-tailed).

Discussion of biomarker results

1. QEEG spectra and eLoreta analysis show upper alpha synchronisation in R BA 6/13 – pre-motor cortex and insula – *What does that mean?*

2. Could this upper alpha rhythm be correlated in some way with Flow and peak performance?

Discussion

1. Sensory information flow necessitates selection of relevant information and suppression of what is irrelevant or interfering – bombardment of sensory information.

2. Alpha's demonstrated role in selective attention (Min and Herrmann, 2007; Snyder and Foxe, 2010) is to *inhibit* the irrelevant aspects of sensory events – decreasing distractibility

How…?

Inhibition–Timing (1)

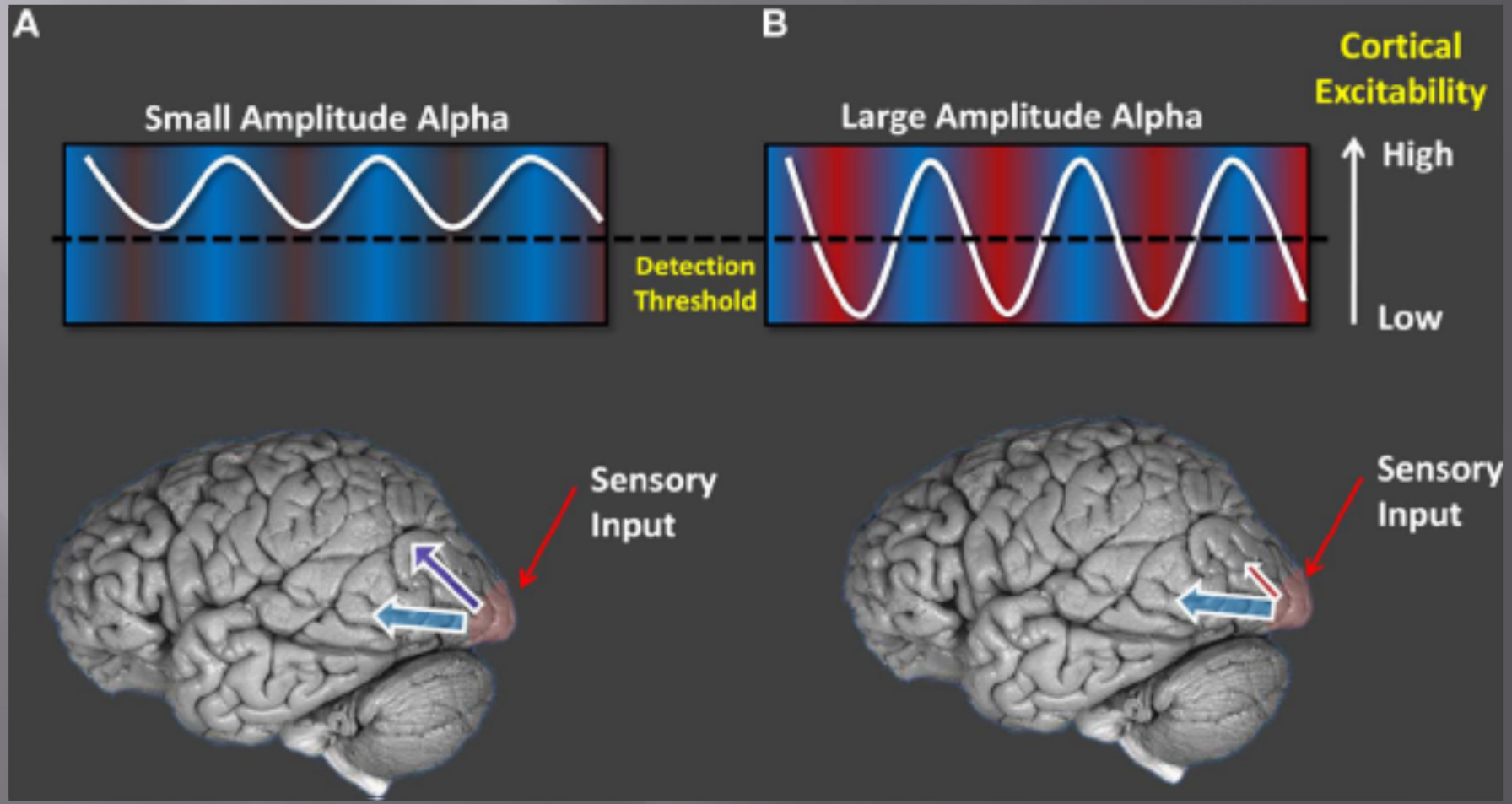
1. Klimesch, et al. 2007 predict an increased focus of attention should *increase* alpha when important inhibitory or timing processes are needed (observed in, e.g., Ray and Cole, 1985; Sauseng et al., 2009)

2. Role of alpha in constraining the *timing* of neural firing (Klimesch et al., 2007)

3. Phase of ongoing alpha oscillations can influence the fine-grained timing of perception (VanRullen et al., 2011)

Inhibition–Timing (2)

- *Pulsed Inhibition*: Mathewson, et al., (2011)



How is this related to Flow and peak performance? (1)

- Dorsal anterior insula is the hub of the Ventral Attention Network (IDs an environmental event that requires a motoric response)

1. It mobilises cognitive and attentional resources, **pulling attention away** from something else to deal with it.

2. If there is a mismatch between expected visceral inputs (gut feelings) and actual visceral inputs, **anxiety** is produced (ventral anterior insula)…

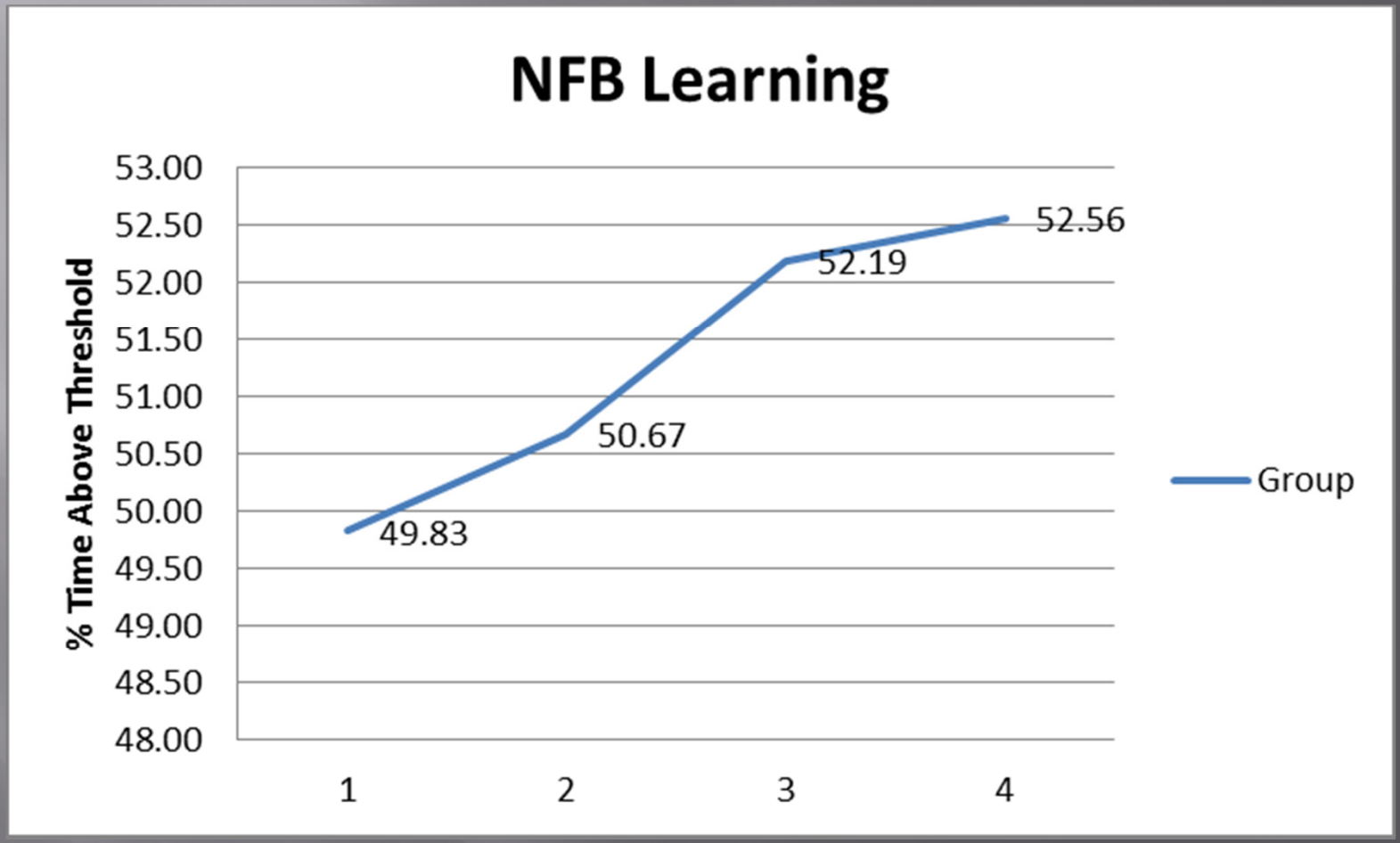
- Both processes interfere with Flow performance
- Alpha NFB training in insula assists dorsal insula processes and inhibits processes relating to anxiety

How is this related to Flow? (2)

In summary… networks within the Insula and between the insula and other brain regions represent the central hub for creating or dampening the Flow state – defined as the ability to keep focus on only relevant information and inhibiting all else… the ability to be able to shift attention to changing salience of information.

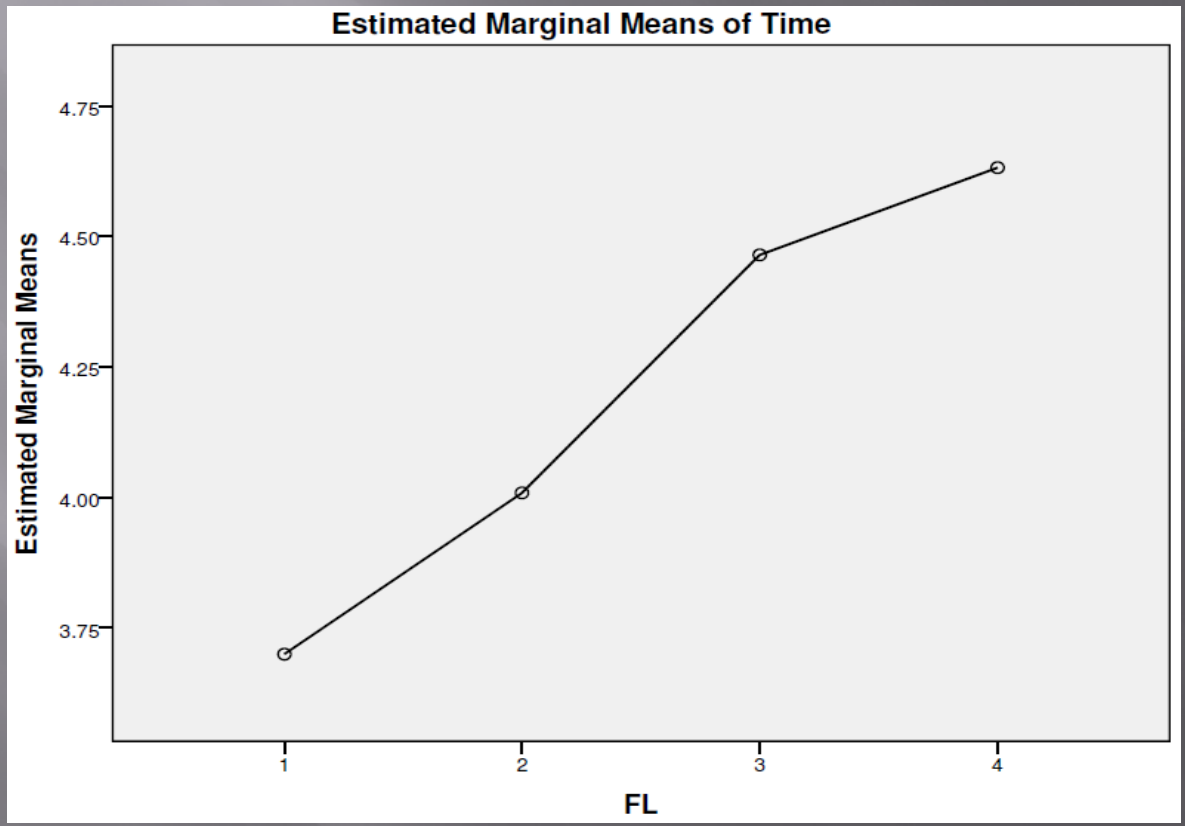
So we trained it…

NFB Results


NFB Learning
% Time Above Threshold
53.00
52.50
52.00
51.50
51.00
50.50
50.00
49.50
49.00
48.50
48.00
1
2
3
4
49.83
50.67
52.19
52.56
Group

NFB Results

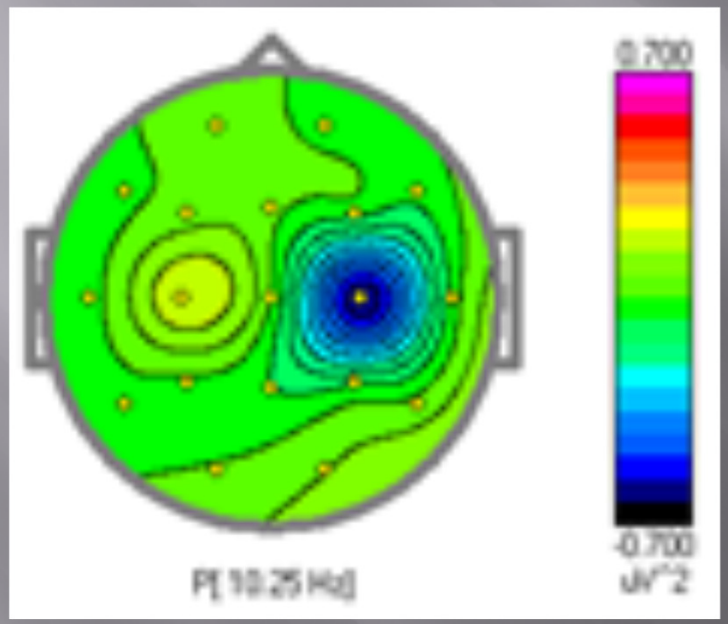
Dimensions of attention (DAQ) - Flexibility

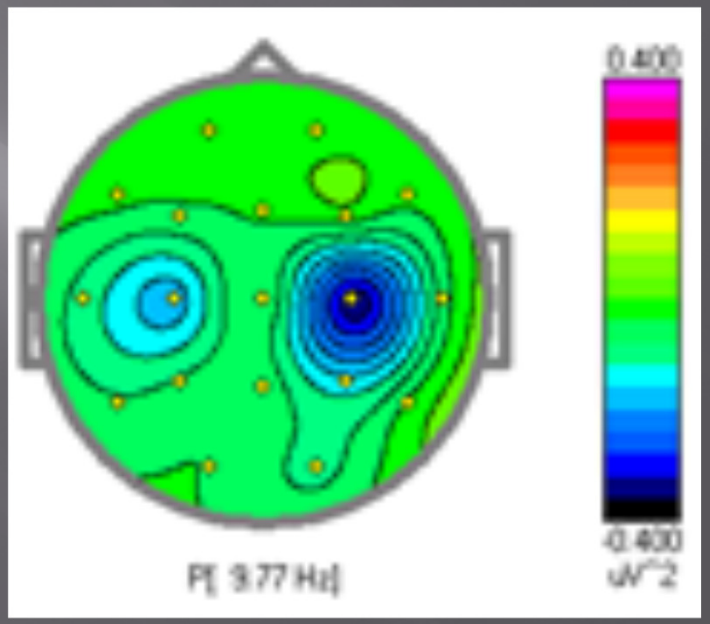


$F(1,9) = 25.52$, $p<.001$,
partial $eta^2 = .739$

NFB Results

Pre-Post C4 Mu during VT

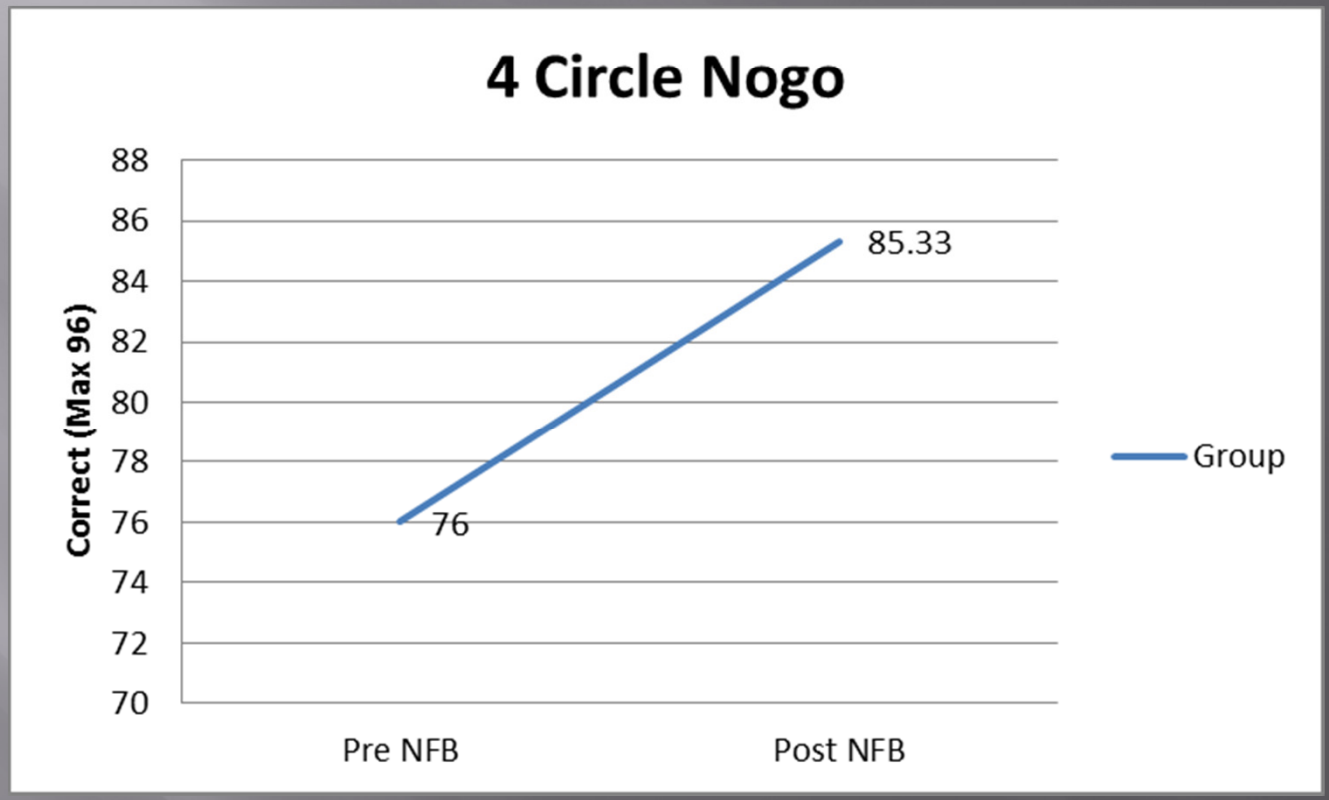




Exp = .618mV^2

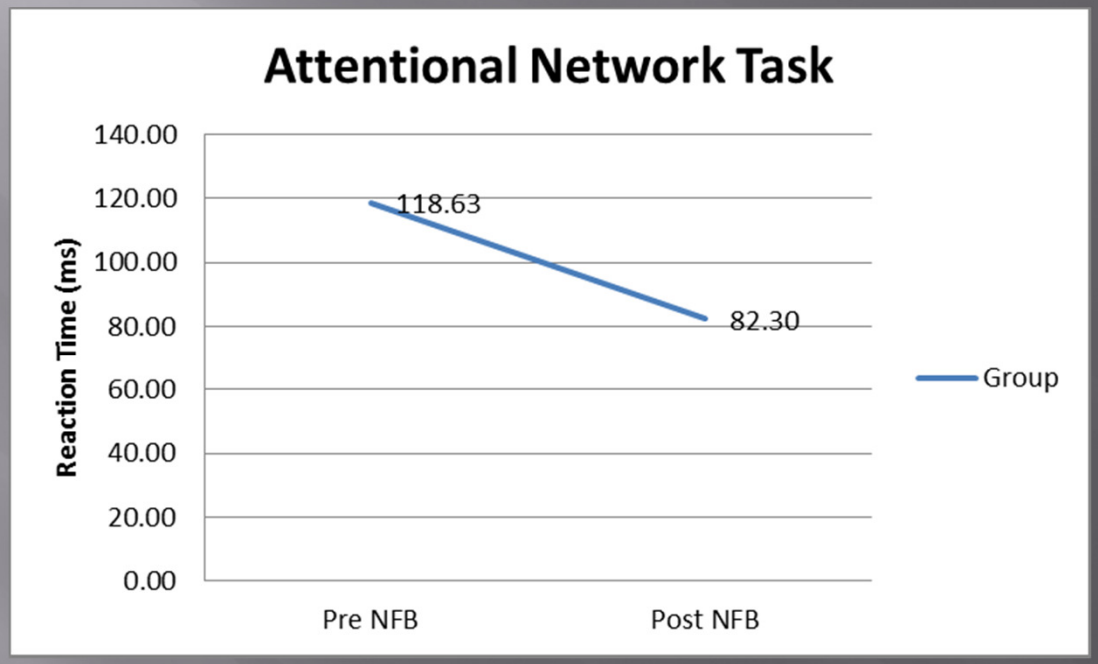
Control = .339mV^2

NFB Results



DAN accuracy to non-target stimuli – correct non-selection of irrelevant information has increased.

NFB training – Poland



Executive functioning: better response time to a target presented with conflicting indicator information – demonstrates higher executive control of irrelevant information

Summary

1. Problem: Heavy reliance on talking therapies and medication for performance enhancement which does not address early psychological components related to peak performance.
2. What is QEEG and NFB.
3. How QEEG and NFB is used for peak performance training *in addition to* current methods. Major Advantage = task-specific psychological skills can be trained outside of regular training to magnify learning.

Future Application

Method can now be applied to any field involving high psychological demands…

1. Skill-specific QEEG analysis and biomarker identification of elite psychological attributes to give an understanding of the relevant neural circuitry to be targeted in that field.

↓

2. Biomarker can then be used for (a) talent identification and (b) Neurofeedback protocol setting.

↓

3. Neurofeedback stimulates brain plasticity in the designated neural circuitry to speed-up learning and increase performance outside of regular training hours.

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