Real-life Neurofeedback

Part III: the theory of the real-life approach to neurofeedback

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- Tuning the training
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Success

Factors that determine success:

1. External influences
   - Weather conditions
   - Imperfection of materials
   - Audience disturbances

   These conditions are either outside of the control of the subject or can be optimized with the proper preparations

2. Task evaluation and execution

Task evaluation

A proper task evaluation is crucial for success, since the goal shows small variations that should be accounted for

- visual inspection of the situation.
- information on external influences (obstructions, wind-, surface-, physical conditions, etc)
- comparison to previously encountered situations.
- possible paths for the body/object (ball, dart, puck, etc)

On the basis of past experiences an ideal path is chosen

➔ MOVEMENT GOAL

Movement protocol

Every task has a different movement protocol that results in the highest probability of success (movement goal)

Representation of movement protocol in the brain

➔ brain state or engram

A movement protocol is executed by the motoric system

Task execution

The motoric system is build up such that it has enormous flexibility and adaptability in the execution of movement sequences within the boundaries that the skeleton configuration imposes

➔➔➔ margin of error for movements

Sensori-motor feedback loop

In the motor cortex, the ideal path to the goal of the movement is translated into motor commands.

The brain sends these commands to the actuators.

The commands are translated into muscle movements.

Information about the configuration of joints and muscle tension is constantly send to the brain.

The brain compares this information (the actual path) to the desired path of the actuators.

An evaluation of the differences between actual and desired path (the error) is made and adjusted motor commands are sent to the actuators.

From before initiation of movement, this is an ongoing cycle of events until the movement is completed.

The error in the movement comes about through small deviations from the calcuted movement goal in the

Errors

In this process, errors are accumulated in:

- information on external influences;
- the choice of the ideal path to the goal;
- the timing of the sending of the correct motor commands;
- information on joint configuration and muscle tension;
- the translation of motor commands to muscle tension.

Optimization

Minimization of the error can be achieved by:

- acquisition of experience in evaluation of the situation;
- repeated training of the task-related motor processes;
- optimization of intrinsic brain processes.

Sport psychology

Optimization of intrinsic brain processes

has been the turf of sports psychologists, who would aim for an optimal general mental well-being, hoping that this would bring sportsmen an optimal mental state for performance.

Peak performance

Also, some sports psychologists introduced the use of peak performance neurofeedback in sports. This implies increasing Alpha activity in clinical sessions.

However, …

Drawbacks

In peak performance there is …

- no information on the actual brain processes associated with the task, but relies heavily on the assumption that high alpha is the best brain state;
- disregard of individual differences;
- clinical session, not relevant contextually;
- operant conditioning rather then classical conditioning;
- state-dependent-learning for passive condition;
- a large number of sessions is required before generalization occurs

Real-life neurofeedback

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In real-life neurofeedback …

- objective assessment of the optimal mental state for performance in the task at hand by actually measuring task-related brain processes;
- individualized training protocols;
- training of the task at hand;
- classical conditioning rather then operant conditioning;

- results can be expected in only three sessions

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Assessment

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Aim: establish a personalized event-locked EEG profile

The event-locked EEG profile is the basis for the real-life neurofeedback training

It shows what EEG frequencies should be increased or decreased for optimal performance

Because the differences between successful and unsuccessful events are very important:

50 % of events should be successful;

50 % of events should be unsuccessful

➔ appr. 50 events of each

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Measurements

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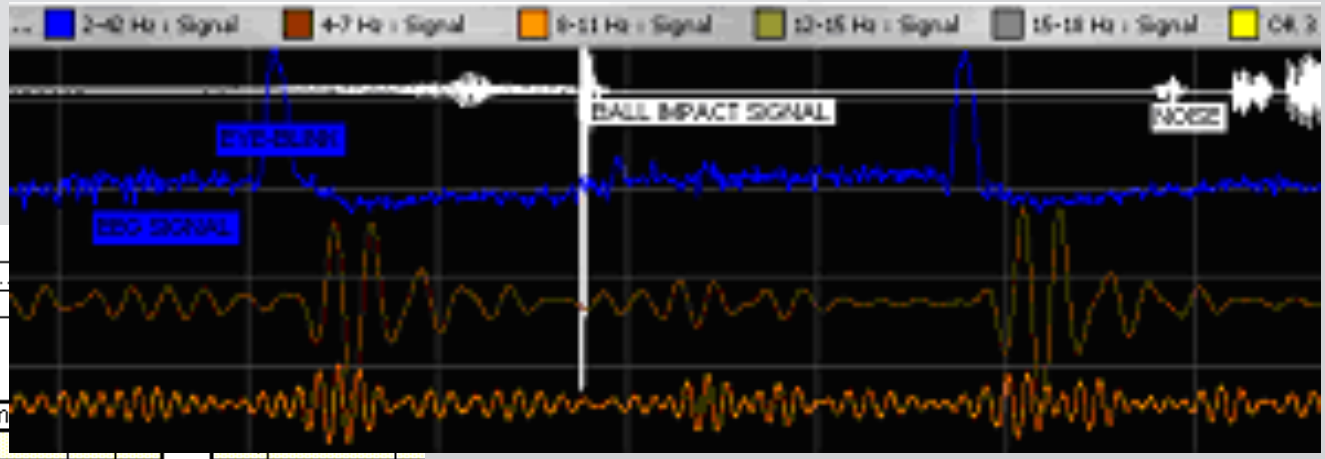
Measurement of the EEG during task-execution

Synchronized measurement of a specific moment in the task

Scoring of events in successful vs. unsuccessful



Name:
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Frequency band amplitudes

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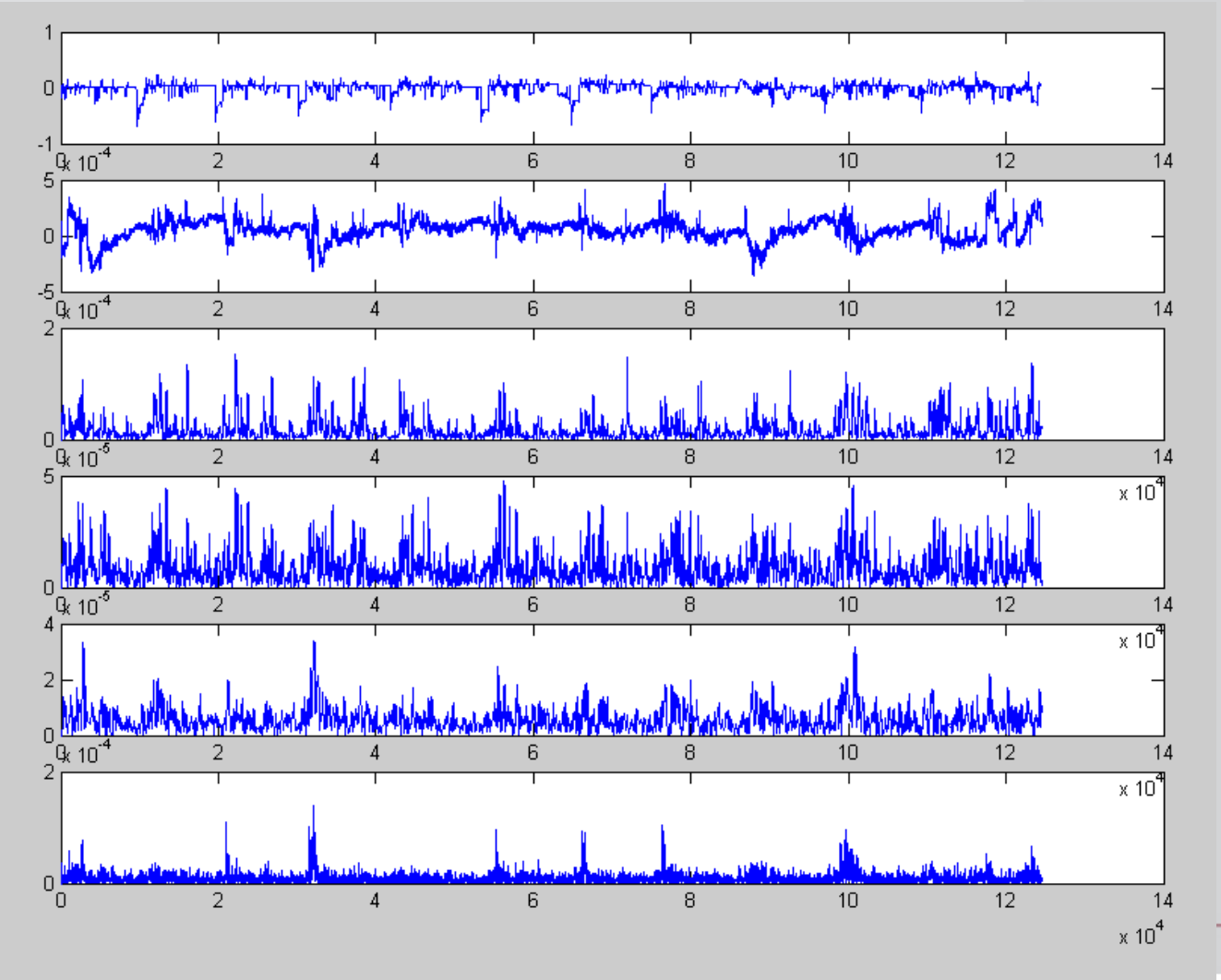
Extract frequency band amplitudes from the raw EEG



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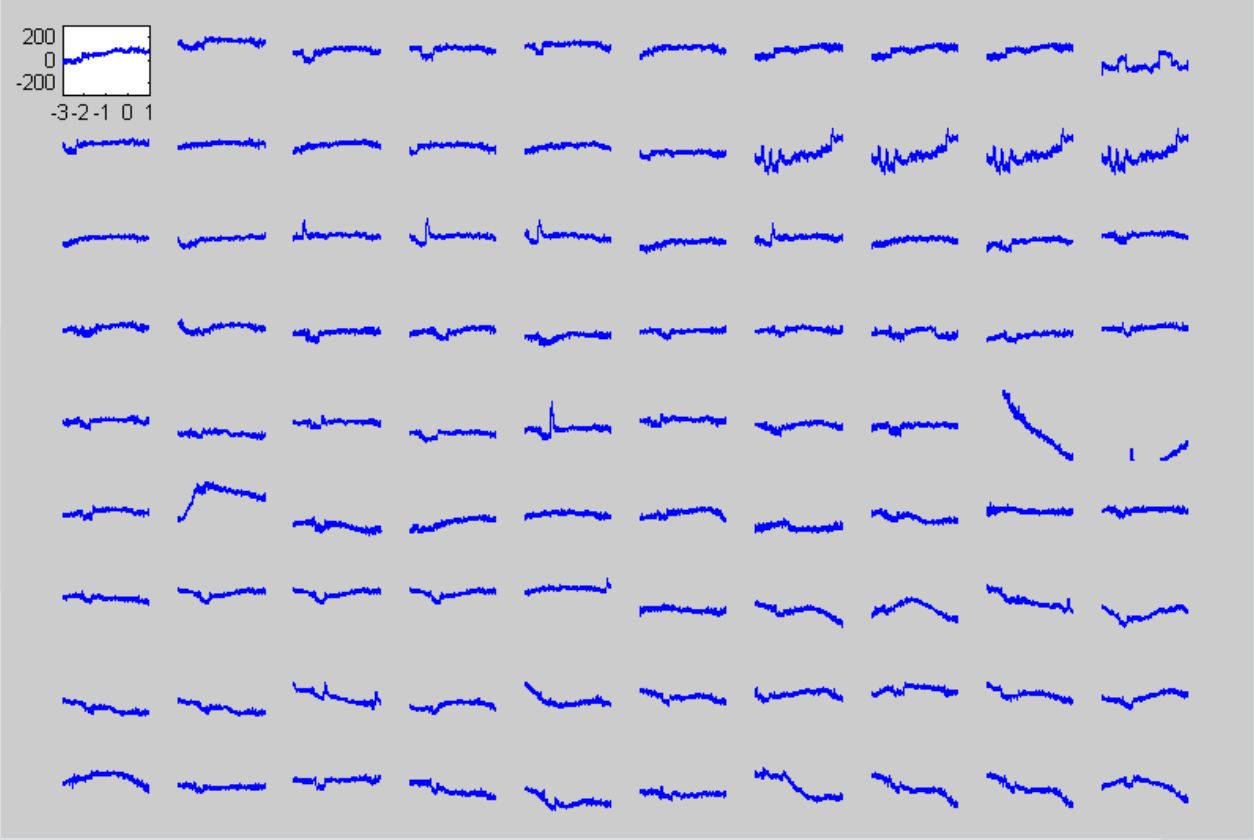
Trial extraction

Extraction of the relevant parts of the EEG: usually from 3 second before to 1 second after event marker [-3 1]



Event-locked averaging

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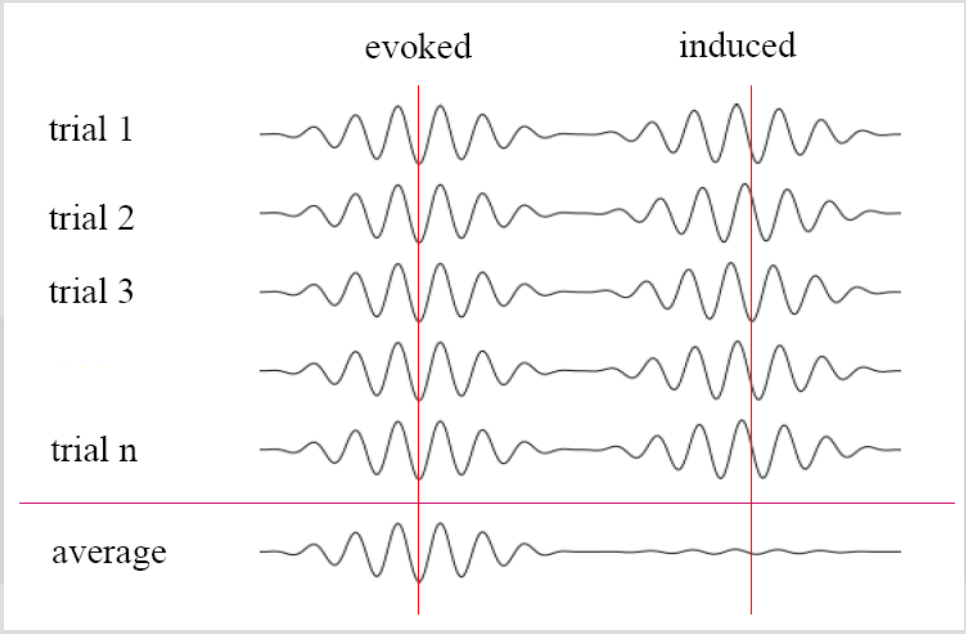
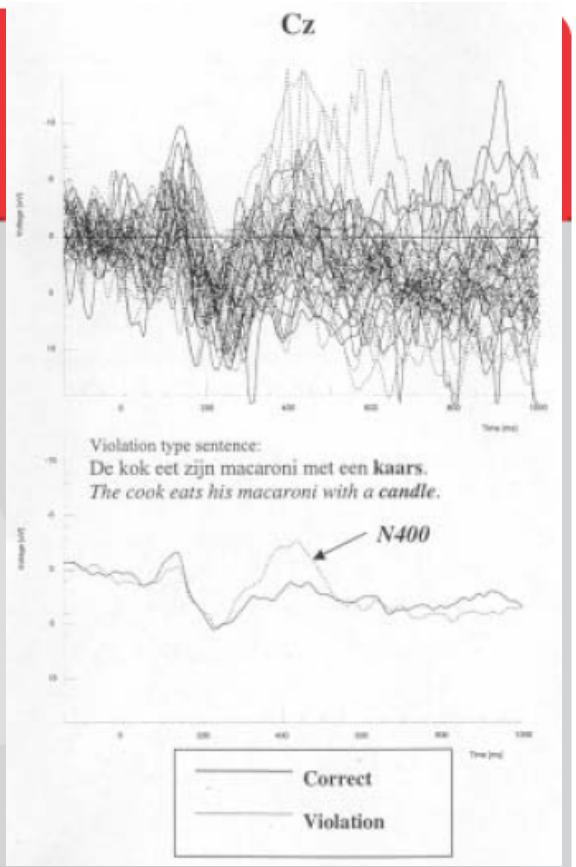
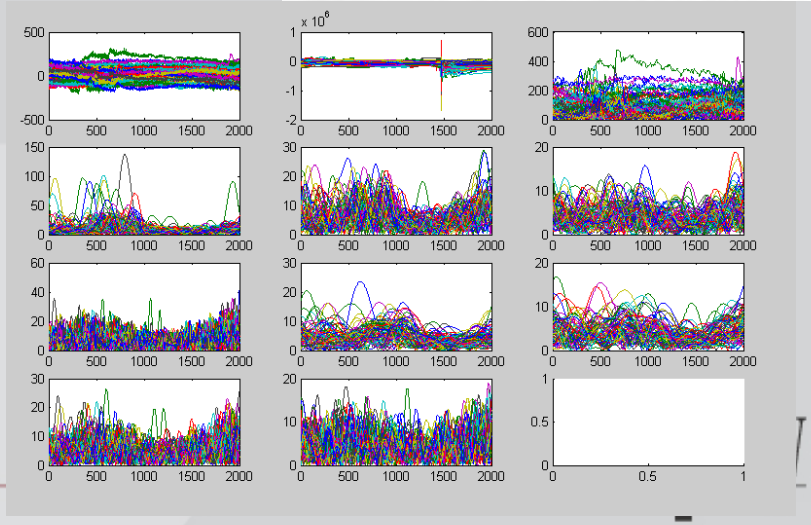
Event-locked averaging of EEG and frequency band amplitudes







ERP

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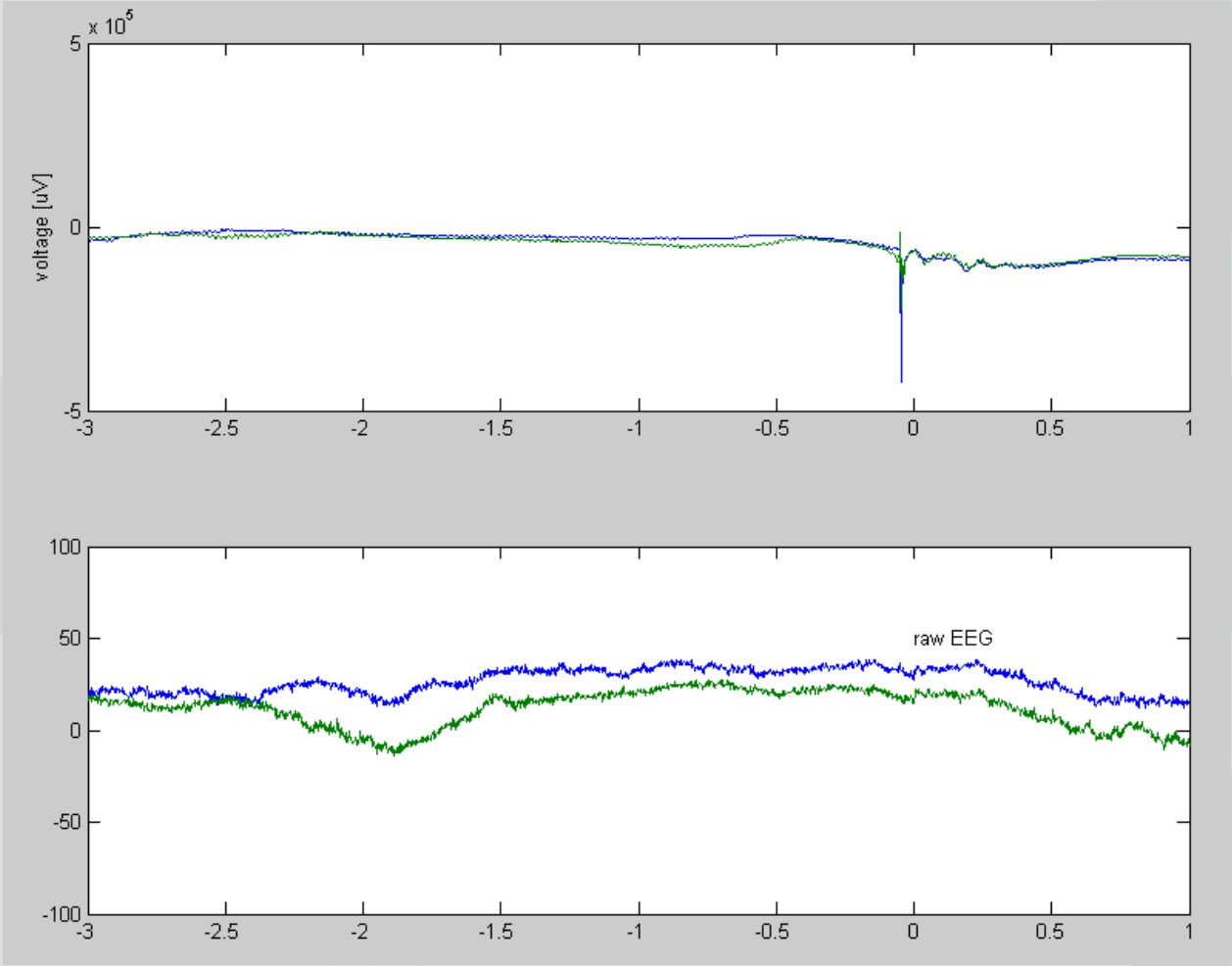
Sensor signal and Event/Related Potential



- Correct event-locking
- Movement artefacts distort ERP

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Event-related EEG

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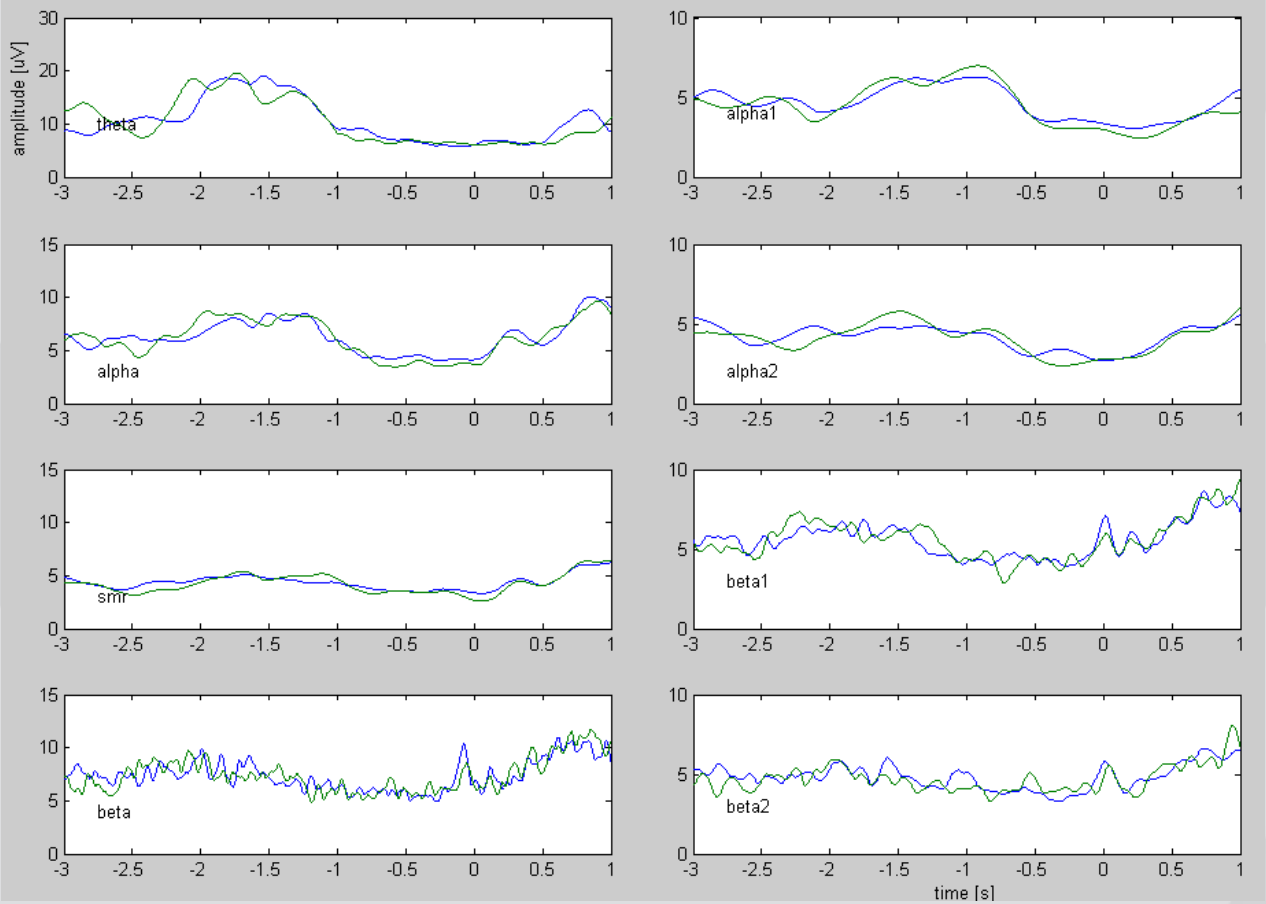
Event-related frequency band amplitudes



- Eye-movement artefact [-2.5 –1]
- Squash
- High alpha for success
- Low theta and beta for success

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Training protocol

Rewards: frequency band amplitudes that should be increased to a specified level

Inhibits: frequency band amplitudes that should be decreased to a specified level

Eye-blink inhibit

EMG inhibit

Impedance inhibit

Training

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Continuous monitoring of the EEG

The amplitudes of the reward and inhibit frequencies are extracted from the EEG in real-time

Feedback is provided in the form of a continuous NoGo tone

The tone stops when all reward and inhibit settings are met and therefore the optimal mental state is reached

The participant should initiate the task asap

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Learning

Repetition of this feedbacked execution leads to learning (classical conditioning of the brain)

The brain learns to recognize the moments of its optimal state of performance.

When encountered with the task in a match, brain activity will automatically shift to the optimal mental state, because it is conditioned to do so.

PET placement

Button the PET EEG on the elastic armband and apply the band on the upper arm which is most convenient for the application.

Make sure the PET EEG is applied such that electrodes can be applied without tension on the wires when moving around.

Good application of the electrodes is most easily achieved with the plug of the PET EEG positioned towards the participants head.

Electrode placement

Only skin electrodes have to be applied, prepare skin with alcohol preppad

Channel 1:

- Measurement electrode (blue): AFz
- Two reference electrodes (yellow): earlobes
- Ground electrode: forehead

Channel 2:

- Inpact sensor signal (event marker)

Impact sensor placement

- Mount the self-adhesive sensor element on the surface that is most receptive of the impact, as close to impact as possible without damaging the sensor.
- Insert the sensor wire connector into the sensor with the red wire connecting to the ‘POS’ side of the sensor. Fixate the connecting parts, ensuring that the sensor wire connector is firmly mounted in the sensor.
- Guide and fixate the sensor wire such that it does not interfere with the event and is convenient for the participant.
- Snap the red sensor wire button onto the blue electrode and the black sensor wire button onto the yellow electrode of the 2-electrode channel of the PET EEG.
- Make sure the length of the sensor wire is convenient for the participant. Fix excess wire on the device.

Operator window: good

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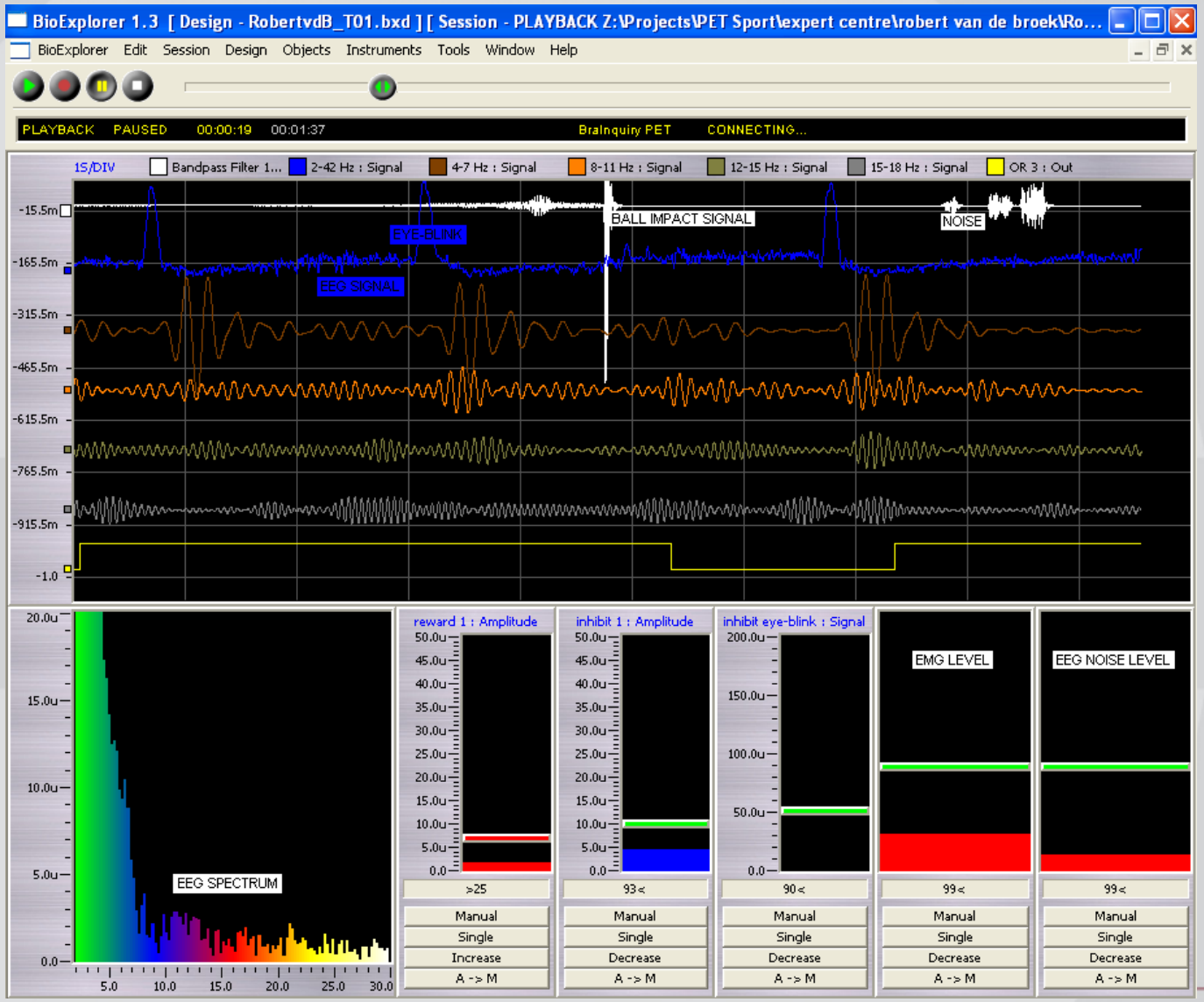

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Operator window: bad

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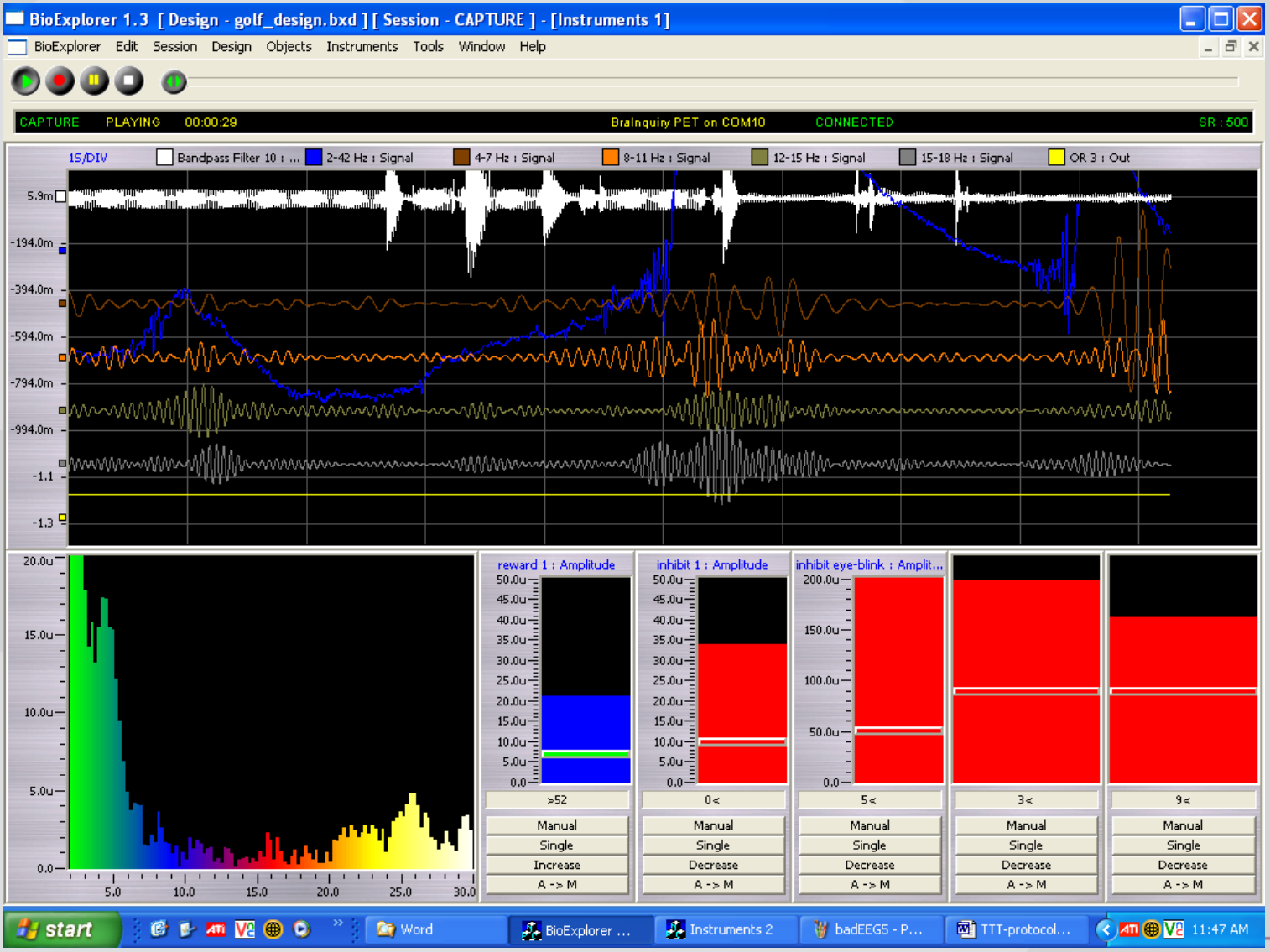

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Impact sensor signal

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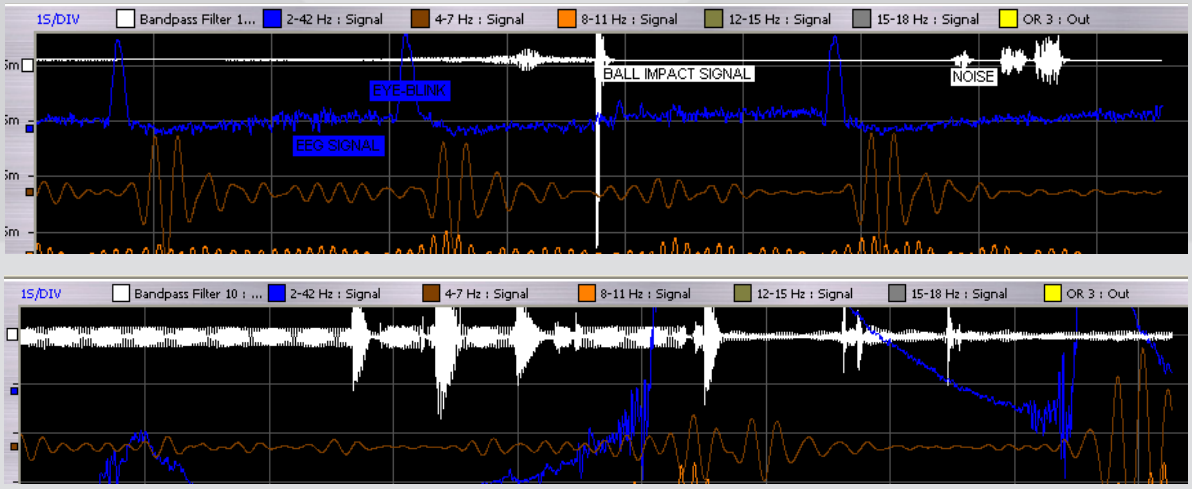
A large peak occurs in the signal every time an impact occurs.

When there is no impact the impact sensor signal is a horiziontal flat line.

The peak indicating impact is much larger as any noise (deviations from flatline unrelated to impacts).



- White band
- No peak
- As large as noise
- No signal

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EMG & Impedance

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The bars are below threshold. The threshold is at 2/5 height of the bar graph range.

- No threshold
- TH not set properly
- Bars exceed TH

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EEG signal

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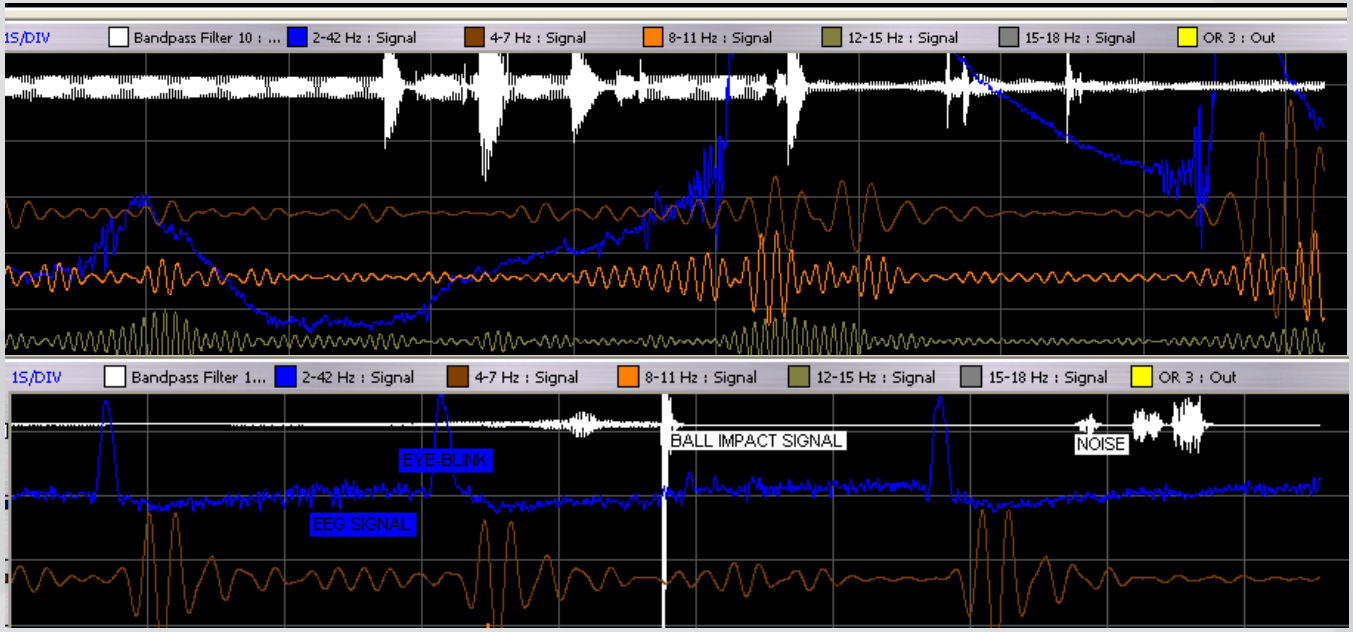
This signal should look scribly and mostly flat. The largest events happening in the EEG signal should be eye-blinks.



- Large, out-of-range fluctuations
- Many, many eye-blinks
- No signal

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Frequency band amplitudes

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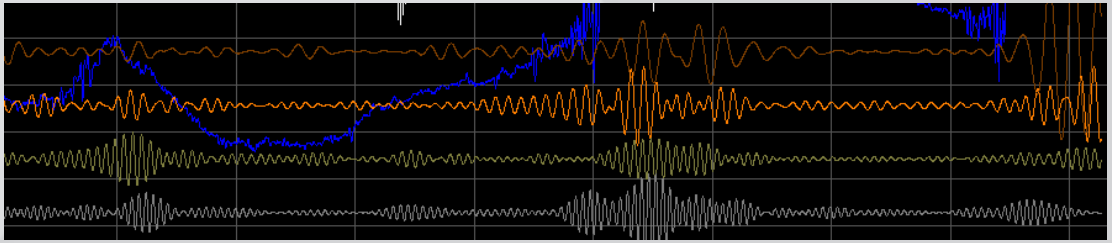
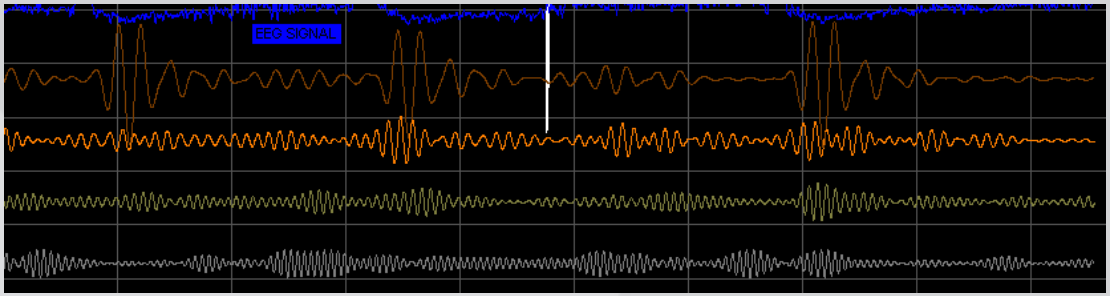
The signals should look like waves, fluctuating in amplitude. From brown to grey (or from top to bottom) the waves should be faster (their frequency should be larger). The frequency band signals shouldn't show too much overlap.



- Large overlap in signals
- Mess of all signals



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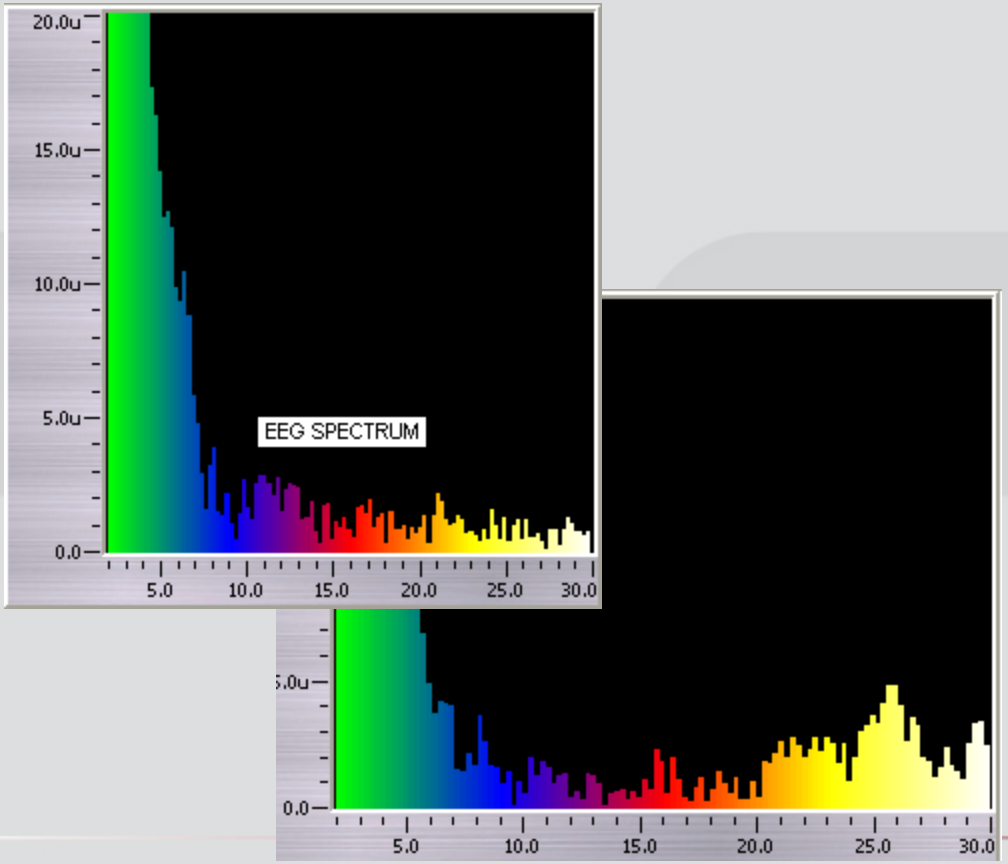
EEG amplitude spectrum

Low frequencies should be relatively high in amplitude: the bars on the left side (low frequencies – theta) should be higher than on the right (high frequencies – beta).



- Completely filled

Feedback signal

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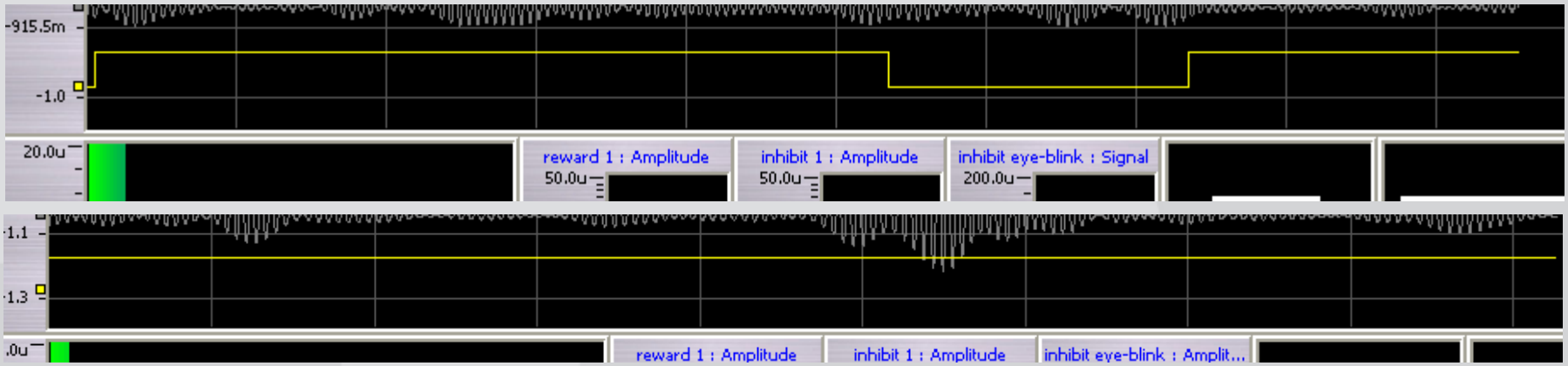
The signal is high for most of the time and low once every 10-20 seconds for two seconds consecutively.



- High all the time
- Low all the time
- Switching too rapidly

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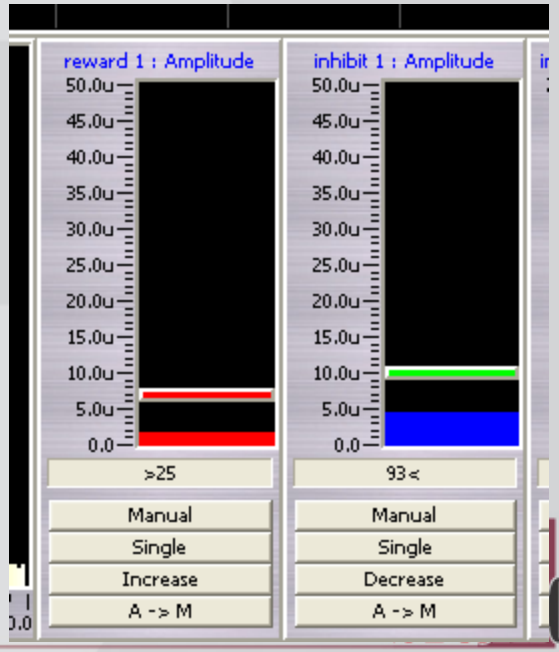
Rewards & inhibits

The bars are within range and somewhat slowly fluctuating.

The ‘reward’ bar color turns from red to blue (pass) when exceeding threshold; the ‘inhibit’ bar color turns from blue to red when exceeding threshold. It could be that the ‘reward’ / ‘inhibit’ graph is constantly blue/red. In this case no ‘reward’ / ‘inhibit’ was set in the training protocol.

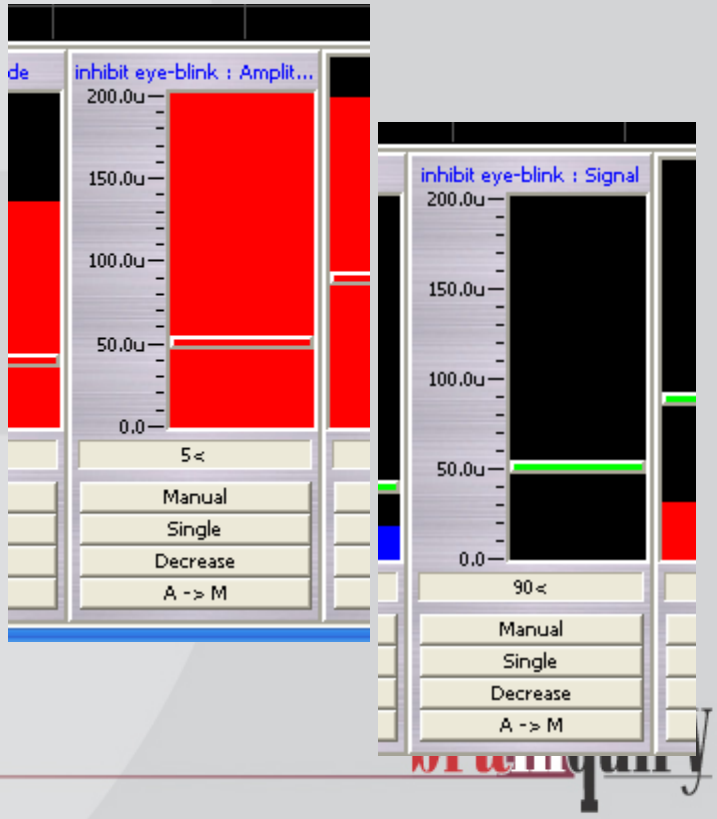
- No threshold visible
- Bar is blue/red/blacvk all the time



Inhibit eye-blink

The bar is within range and shoots up over the threshold whenever an eye-blink occurs. The bar color changes from blue to red when exceeding threshold.

- No threshold is visible
- Too excessive eye-blinking



A:Participant instructions

- first you have an opportunity to warm-up;
- then, you will play a few series at a difficulty level at which 50 % of all events are successful;
- the assessment consists of 10-12 series of 10-12 events at the 50 % difficulty level;
- it is important to:
  - put in your normal routine;
  - minimize (head-/eye-)movements (pre-shot period);
  - try to be relaxed;
  - avoid impact sensor contact except when performing the task.

A:Preparation

Prepare the data acquisition:

- start the BioExplorer software;
- open the assessment design;
- show the operator window;
- start reading data from the PET EEG.

A:Warm-up and data check

Let the participant perform a warm-up round,

Meanwhile evaluate the impact sensor signal and EEG signals in the operator window.

Provide additional instructions to the subject when necessary.

In the assessment session it is not necessary to regard the feedback signals.

A:50 % difficulty level

Let the participant choose an event from which he/she thinks to successfully perform at 50 % of all events;

Perform 3-5 series of events and adapt the difficulty level according to the success percentage until the 50 % level is relatively accurately known;

Make a description of the characteristics of the event (goal, distance, etc) on the scoring form.

A:Assessment

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- prepare the set-up for action;
- start recording the data saving it under a unique filename;
- cue the participant he can commence playing, making sure to wait appr. 6 seconds after pressing ‘Play’ before performing the first event;
- score the events for success;
- meanwhile, observe the impact signals and the EEG on the screen and react to difficulties;
- make a note of everything out of the ordinary in the remark column ;
- when the participant finished the series stop recording data, making sure to wait appr. 3 seconds after the last event;
- repeat for 10-12 series;

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A:Assessment data

When enough artefact-free data is gathered, take off the sensor and the head electrodes or let the participant do this him/herself

Close BioExplorer and turn off the PET EEG or run another participant

Mail the data to michiel@brainquiry.nl to request an analysis of the assessment. Scan the scoring form and include it in the mail or fax the form to faxnumber: 0031842245579.

T:Participant instructions

- first you have an opportunity to warm-up;
- the first number of series of events are without feedback and essentially identical to the assessment series; then, a number of feedback series are performed; this is repeated for a second time (A-B-A-B);
- in the feedback series you will hear a continuous tone; this tone is linked to your brain activity; if the computer detects your optimal mental state (as determined in the assessment session), the tone will cease;
- prepare yourself for performing the event in your ordinary routine, wait for the tone to go off and as soon this occurs initiate the event;

T:Participant instructions (2)

- the tone will be gone for two seconds; when you made the decision to initiate, carry out the event irrespective of the possible return of the tone;
- when you are waiting for the tone to go off and this does not happen for a long time, you should step back and prepare again;
- don't rush; wait for a second or third cue when you are not completely ready to perform according to your normal routine;
- it is important to:
  - play in your normal routine as much as possible;
  - minimize (head-/eye-)movements (pre-shot period);
  - try to be relaxed

T:Preparation

Prepare the data acquisition:

- start the BioExplorer software;
- open the training design;
- show the operator window;
- for giving auditory feedback to the participant, install speakers or wireless headphones to your PC/notebook or use your notebook speakers;
- start reading data from the PET EEG.

T:Warm-up and data check

Let the participant perform a warm-up round,

Meanwhile evaluate the impact sensor signal and EEG signals in the operator window.

Provide additional instructions to the subject when necessary.

T:No Feedback

Perform the first No Feedback series (appr. 5 series) as in the assessment

- keep the speakers/headphones turned off;
- name the data files in a consistent meaningful manner;
- on the scoring form, note the event characteristics, the series name (S0…) and the type of the series (NF/FB);
- score the events for success;
- observe and evaluate the yellow feedback signal: the signal should be high most of the time and low once every 10-15 seconds for two seconds;
- fine-tune the reward and inhibit thresholds;
- save the fine-tuned training design.

T:Feedback

Perform the first Feedback series (appr. 5 series) similar to the NF series, BUT:

- switch on the feedback by turning on the speakers/ headphones;
- the differences from the No Feedback series are mainly on the side of the participant; react to difficulties by tuning the reward and inhibits
- repeat the instructions for the participant if necessary.

T:ABAB

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Repeat the AB for a second time.

You can divert from the A-B-A-B design in later training sessions and increase the number of series of the feedback type.

When the training is fininshed, take off the head electrodes or let the participant do this him/herself.

Close BioExplorer and turn off the PET EEG or run another participant

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Tuning eye-blinks

An individual approach in handling eye-movement activity is necessary.

Brainquiry has evaluated the eye-movement activity of your participant in the assessment session and adapted the training design accordingly.

However, eye-movement activity in feedback series can be different from the assessment because processes (self-paced vs. on-command) have changed.

When this happens, the ‘inhibit eye-movement’ threshold can be adapted.

Tuning slow artefacts

Also, the ‘inhibit eye-blink’ threshold will inhibit the feedback tone when the EEG signal is out of range (large slow fluctuations).

When the signal is within range of the ‘inhibit eye-blink’ but stays above threshold continuously, the threshold can be temporarily heightened until the EEG signal stabalizes.

‘Follow’ the trend of the signal with the threshold by dragging the threshold with the mouse.

Tuning rewards and inhibits

Brainquiry has extracted threshold values for the reward and inhibit frequencies.

Try to change the threshold settings, such that the feedback is pleasant for the participant.

Usually, this is the case when the feedback is stable and predictable, ceasing every 5-15 seconds.

This can be individually different, depending on the speed and character of a player.

Tuning rewards and inhibits

The Assessment Report indicates the weight that is given on a reward or inhibit.

In most cases, the reward will be the most critical for success. Include this in the fine-tuning: if the reward is most important, leave the threshold high and highten the threshold of the inhibit and vice versa.

Evaluate what percentage of the the reward/inhibit is above/ below threshold in the pre-shot period.

Pilot (1)

- Aim:

  investigate whether differences exist in EEG activity for successful vs. unsuccessful events

- Method:

  ‘Real-life’ measurement of the EEG during golf putting

- Outcome:

  recognizable and reproducable EEG patterns for successful and unsuccessful puts

Pilot (2)

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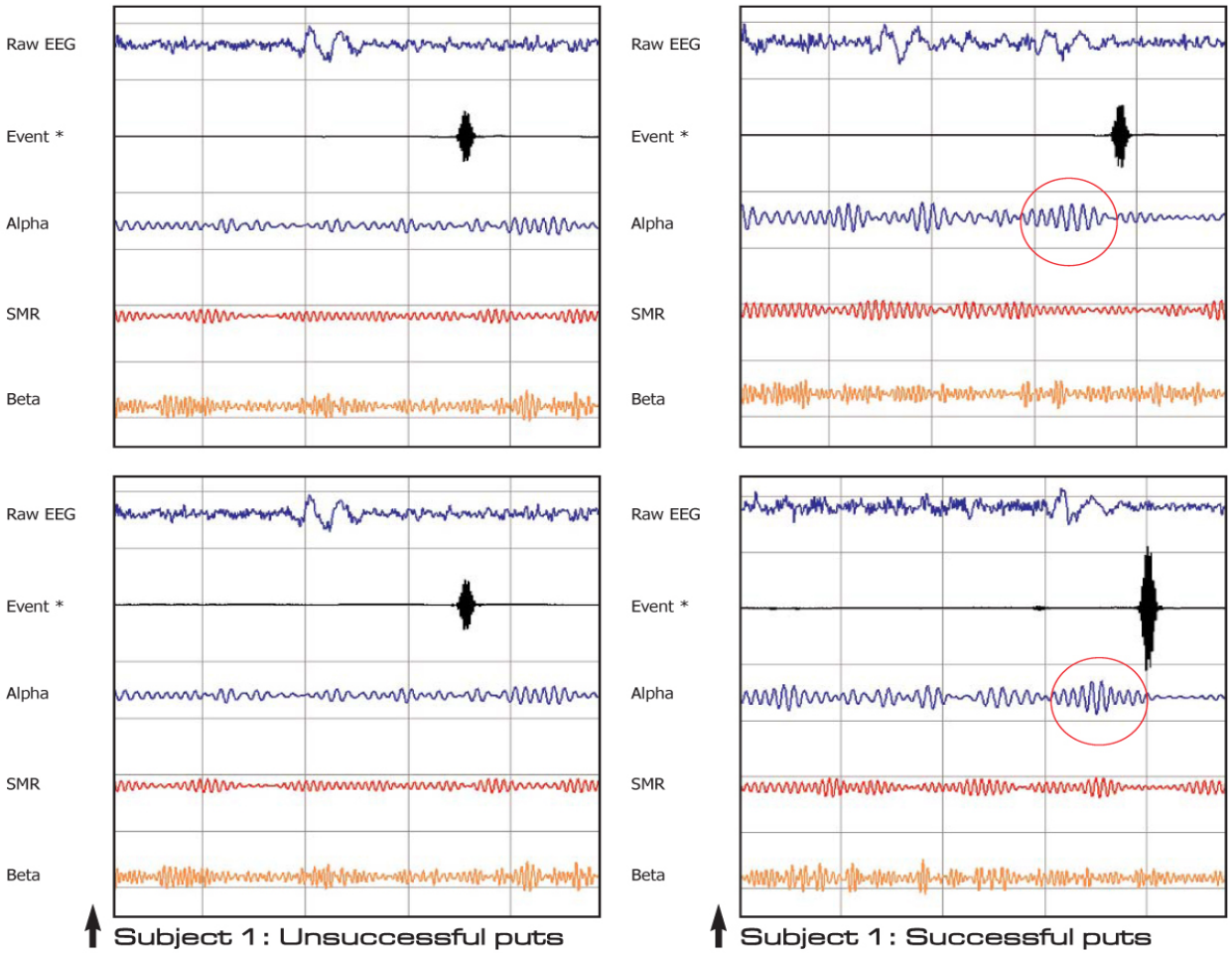

Difference in puts

In these pictures you can see the brain wave patterns of two unsuccessful and two successful puts of one subject. The brain wave pattern in the successful puts showed a clear burst of alpha before the ball impact.
During the unsuccesfull puts this was absent.

** The burst in this event is the ball impact.*

Literature

- Crews & Landers (1993)

  Electroencephalographic measures of attentional patterns prior to golf put. Med Sci Sports Exerc, 25(1):116-126.

- Landers et al. (1991)

  The influence of electrocortical biofeedback on performance in pre-elite archers. Med Sci Sports Exerc, 23(1):123-129.

- Konttinen et al. (2000)

  Aiming routines and their electrocortical concomitants among competitive rifle shooters. Scand J Med Sci Sports, 10(3): 169-177.

Study

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- 6 participants (handicap 12.3, SD 5.6)
- Assessment + 3 real-life neurofeedback training sessions
- On-course/off-course?
- Recordings:
  - FPz against linked earlobes
  - event channel of ball impact
  - success scoring

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Assessment procedure

- 50 % successful putting distance (PD_{50})
- 8 x 10 puts
- Event-locked averaging of the EEG for successful vs. unsuccessful puts: event-related EEG
  - ERP
  - Frequency band amplitudes (theta, alpha, SMR, beta, alpha-1, alpha-2, beta-1, beta-2)

Assessment results: Subject 1

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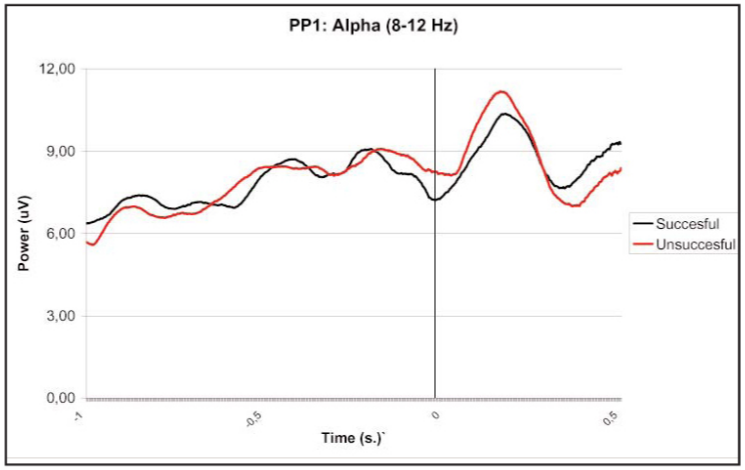

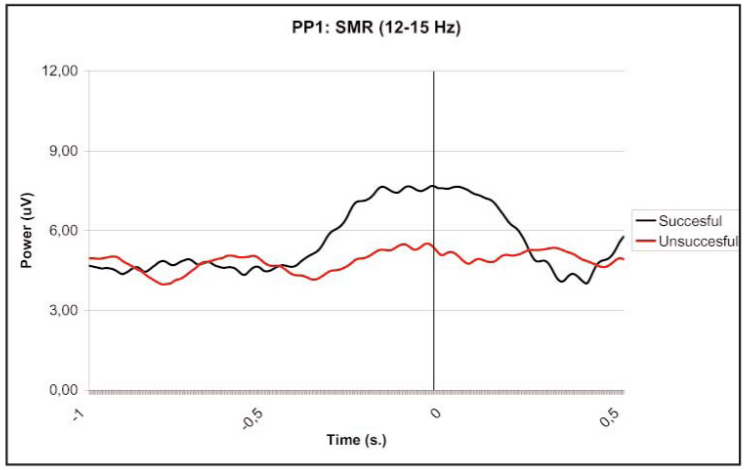

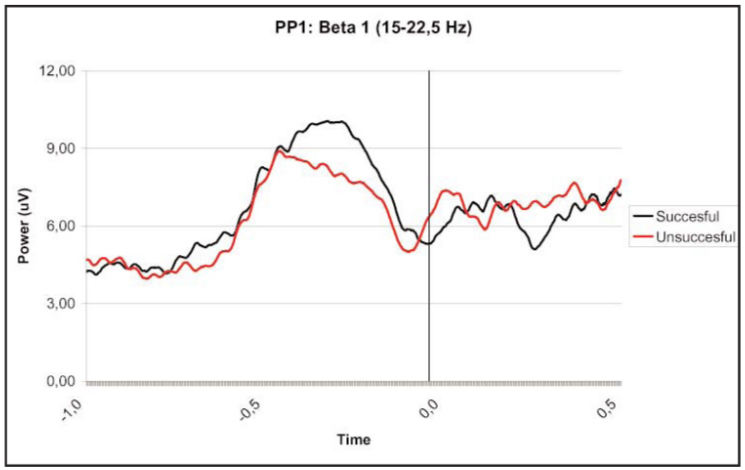

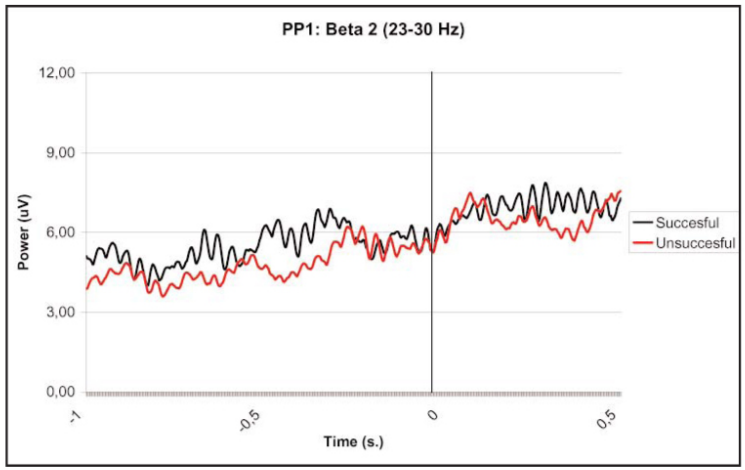

Subject 1

This subject shows a very clear pattern in SMR and Beta 1. There were no differences in the Alpha and Beta 2 ranges.

Assessment results: Subject 2

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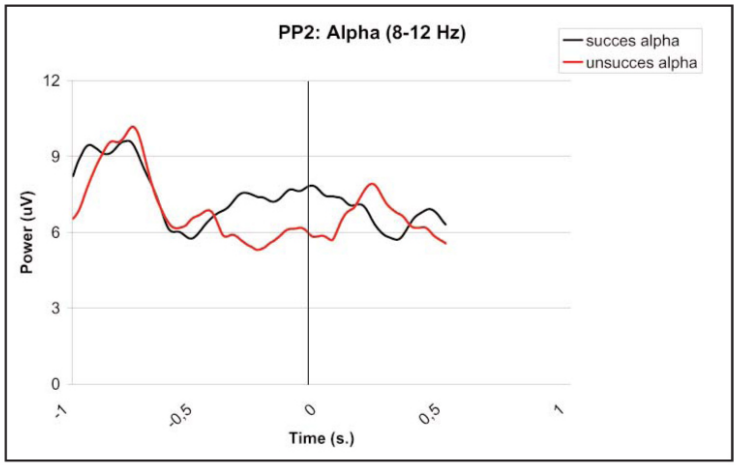
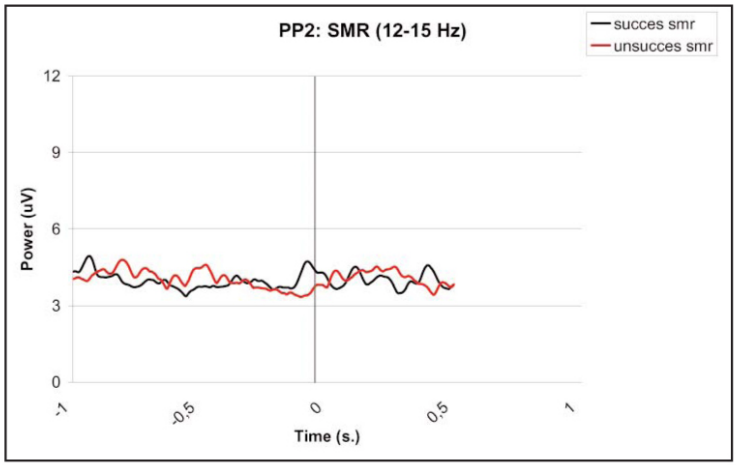


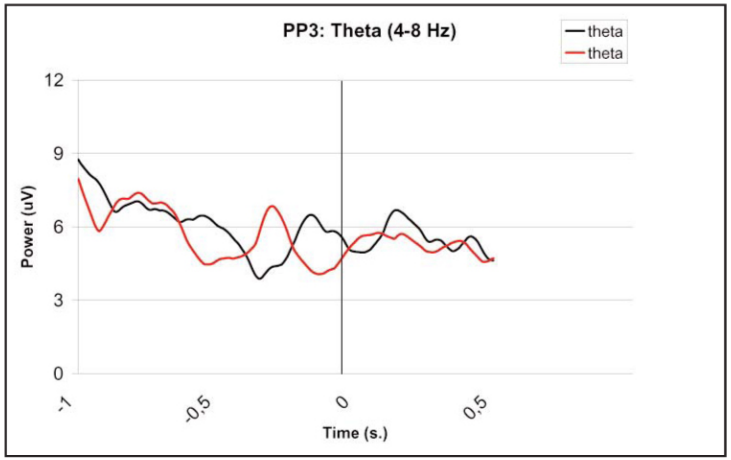


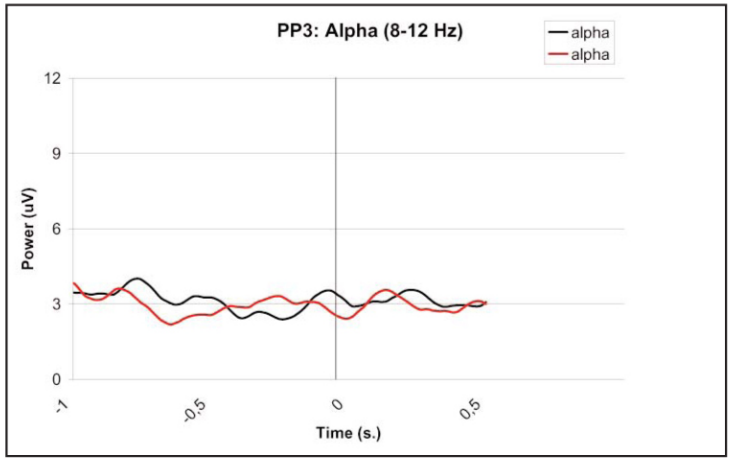
Subject 2

This subject shows a very clear pattern in Alpha and a small difference in SMR. There were no differences in the Beta 1 and 2 ranges.

Assessment results: Subject 3

PERSONAL EFFICIENCY TRAINER®





Subject 3

This subject shows a shift in Alpha and Theta. There were no differences in the Beta 1 and 2 ranges which could be interpreted as a timing effect; e.g. the preperation started to early.

Training procedure

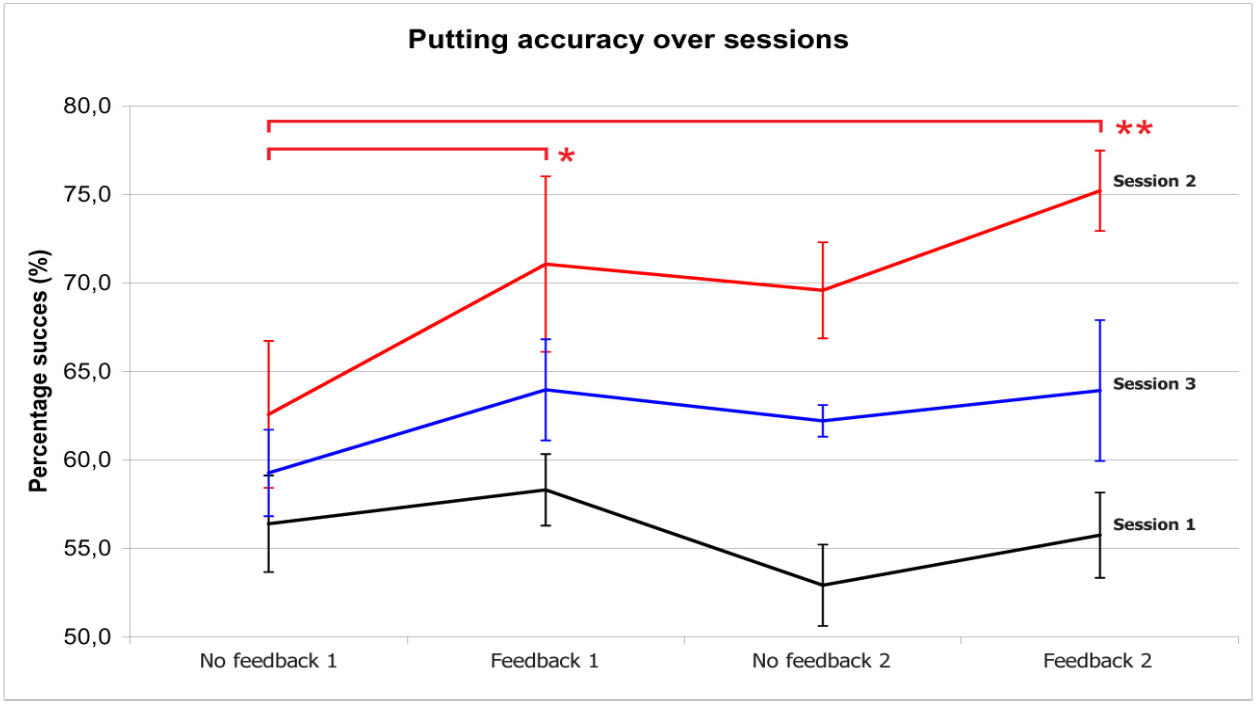
PERSONAL EFFICIENCY TRAINER®

- Personalized training protocols based on the individual event-locked EEG profiles
- 4 x 80 puts from PD_{50} in an ABAB design
- Feedback condition:
  - continuous NoGo tone
  - ceasing when in the optimal mental state for performance
  - eye-blink and EMG inhibits

brainquiry

Training results

PERSONAL EFFICIENCY TRAINER®



Putting accuracy

This figure clearly shows the effect of feedback during the golf putting. The feedback conditions clearly showed an increase in putting accuracy, and highly significant effects were found on session 2 with an increase of 10%.

Discussion

- Real-life neurofeedback
- Location
- Control group
- Sham feedback