Combined EEG and Eye-tracking in Sports Skills Training and Performance Analysis

An Archery Case Study

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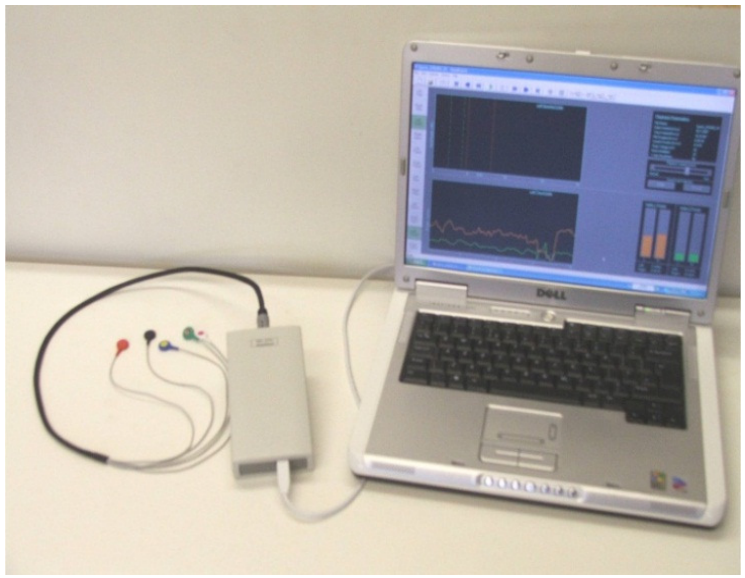
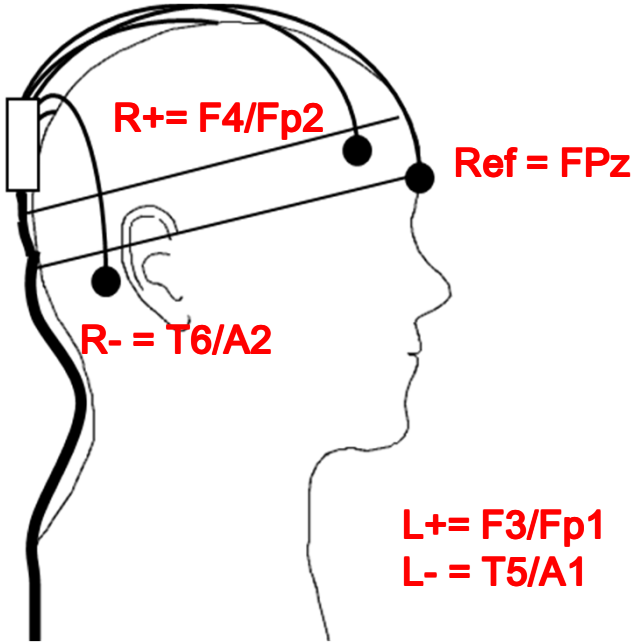
Aim: To enhance mental performance in sport

- Success in sport requires a winning mind-state and visual skill, as well as high level of talent, physical performance, tactics, etc.
- New mobile sensor devices are now available
  - Compact EEGs to measure neurocognitive activity [1]
  - Eye-tracking systems to measure visual focus
  - Recordings can be made during 'real-world' training to compare performance to mental and visual focus, different coaching interventions, etc.
  - Live feedback of data (e.g. sound) to athlete and/or coach
- We present an evaluation of an EEG study in archery
  - Measured and compared mental states versus scores & skill
  - Results vary as a function of level of athlete performance

Compact EEG Set-up



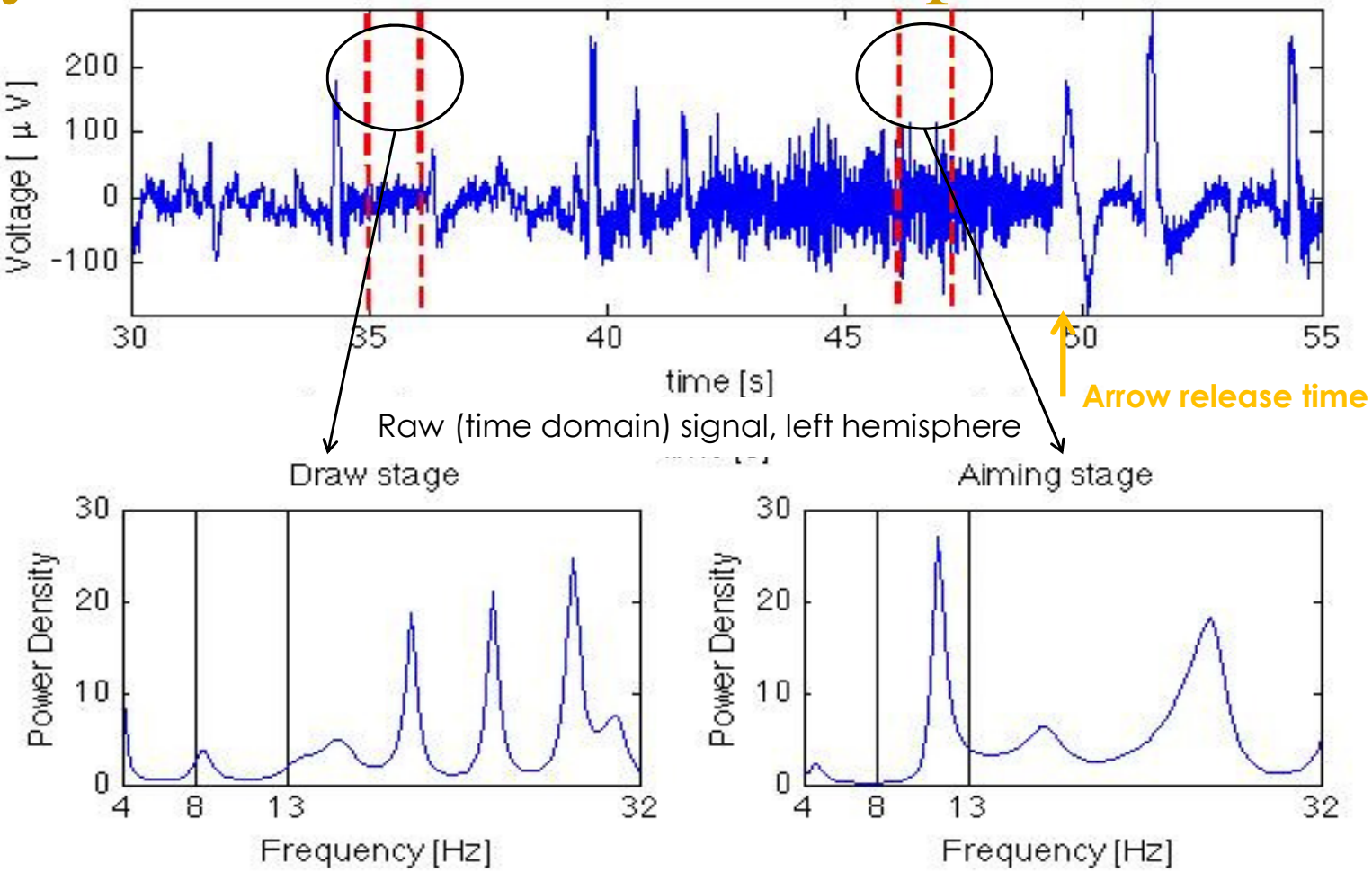


- 5 leads: 2 bipolar channels plus reference lead (active ground)
- 128Hz sampling rate, 24-bit ADC
- Standard passive ECG electrodes used (locations as above)
- Location of electrodes chosen for convenience (no hair) and
- To measure general frontal cortex neurocognitive activity from 4Hz to 45Hz (theta, alpha, and beta frequency bands)

Study Protocol

- Experimental details :
  - 8 recurve archers in practice sessions
  - County level, near elite and elite archers
  - 3 separate sessions
  - 176 shots analysed and compared with scores
- EEG Spectral analyses were produced for each shot
  - To obtain frequency of brain activity at recording sites
  - Standard Fast Fourier Transform (FFT) and Alpha-Active proprietary[2] autocorrelation algorithms applied to the raw (time-domain) EEG
  - Frequencies are related to particular mental states
  - Progression of frequency vs time visualised with heat plots
  - Frequency data was split into three bands for study
  - Frequency correlation studies: shot to shot, archer to archer

Key characteristics of EEG spectrum

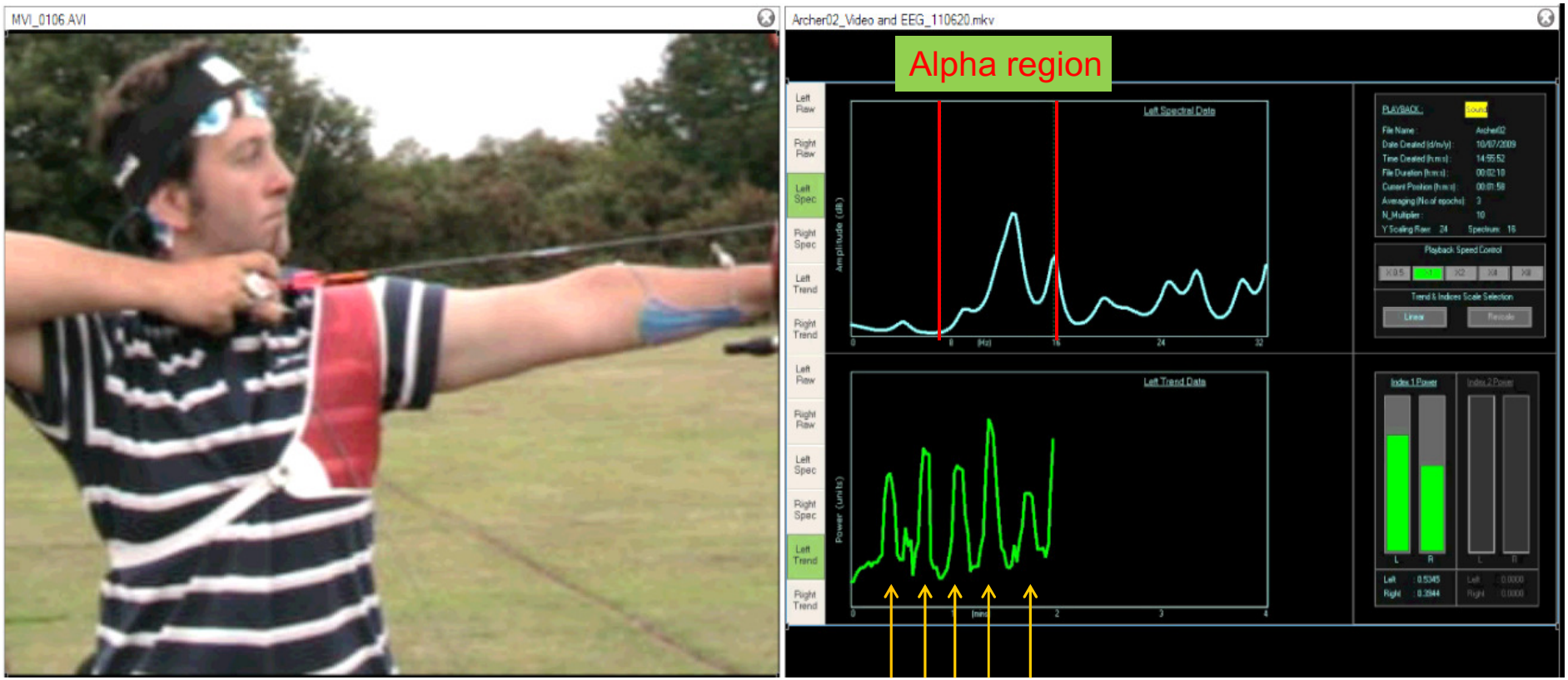


Spectrum (frequency domain) signal, left hemisphere

Key frequencies extracted in this study:

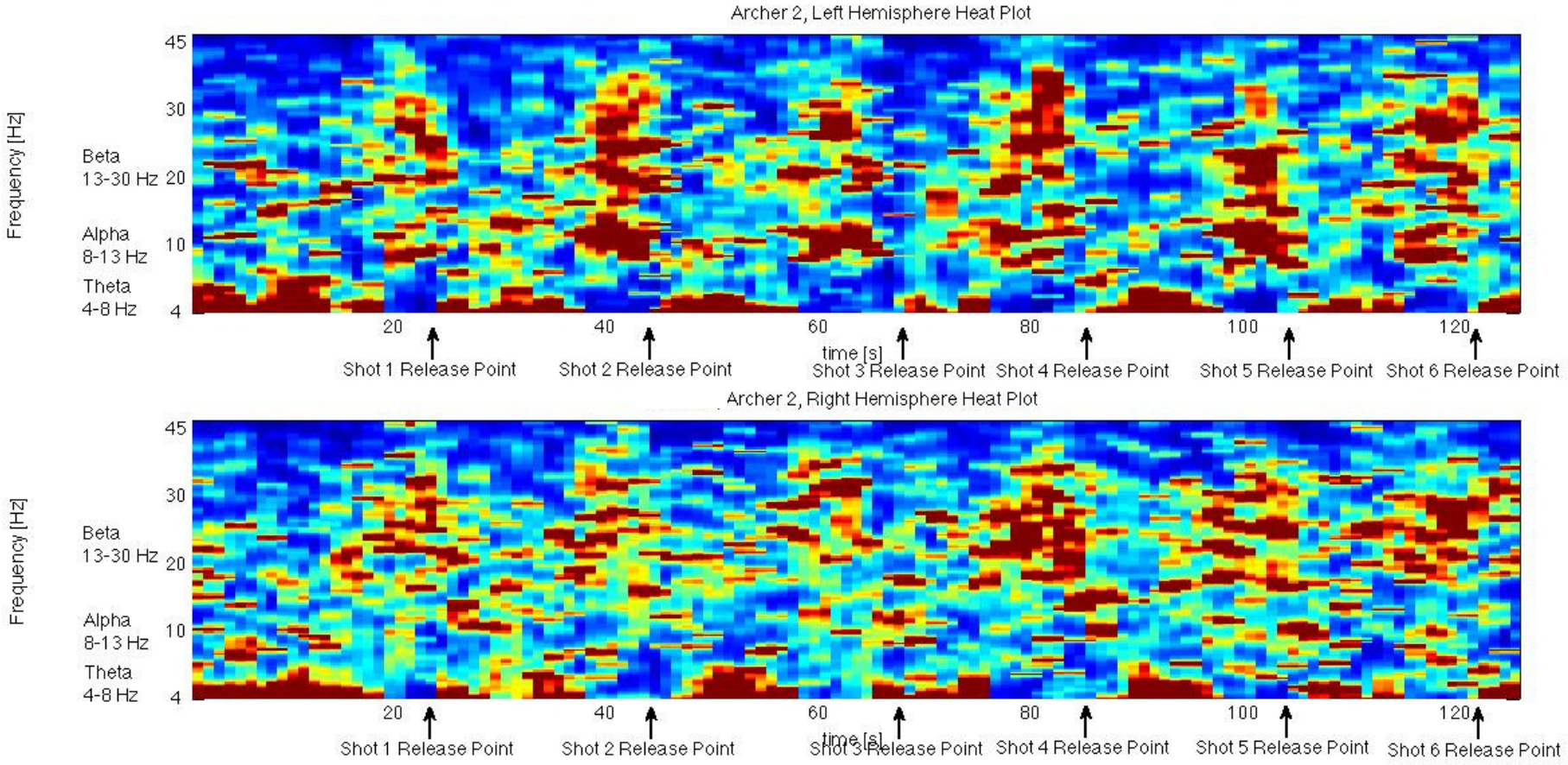
- Theta, 4 to 8 Hz: often a transition state to alpha
- Alpha, 8 to 13 Hz: internally focussed, relaxed, not thinking
- Beta, 13 to 30 Hz: externally focussed, alert, thinking

Data Capture Protocol



- EEG with simultaneous sound recording for arrow release time (↑)
- Each arrow identified and location on target mapped (as well as score)
- Conventional video & sound recording
- Upper GUI shows left spectrum epoch at 6th arrow release and lower GUI shows alpha trend (alpha/whole spectrum) versus time, in minutes

Results

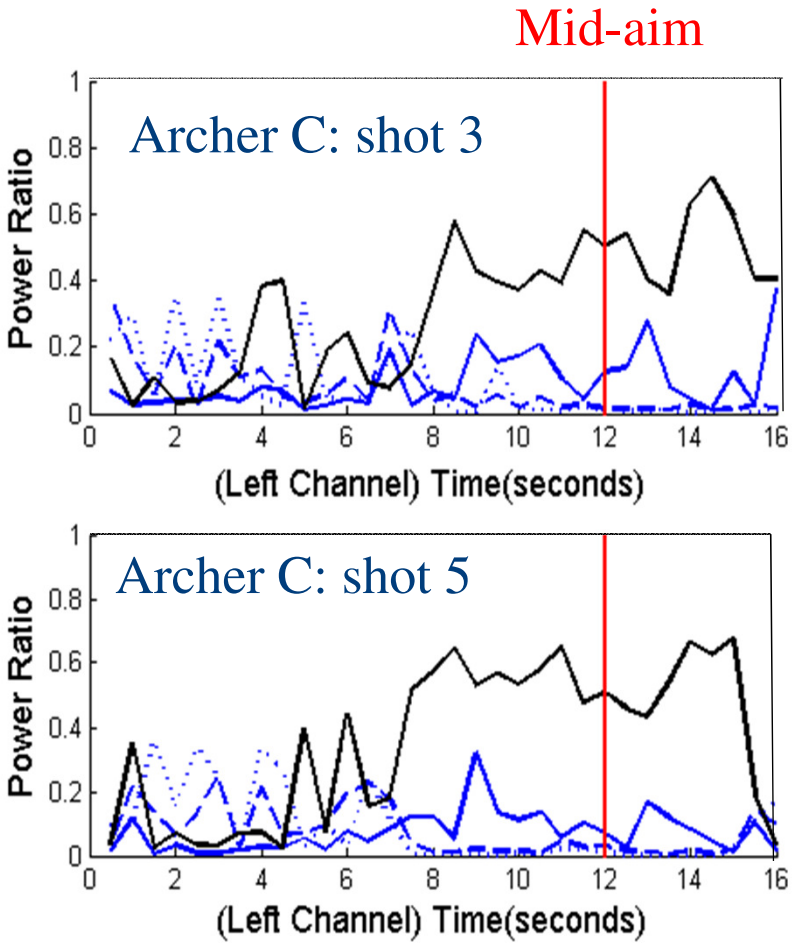


Scores	9	9	9	9	8	7

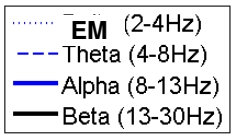
EEG heat plot results for left and right side of brain.
X scale is seconds, showing arrow release times, Y scale is frequency, colour scale is intensity of EEG spectrum, red is most intense, blue is least intense.

Data Analysis

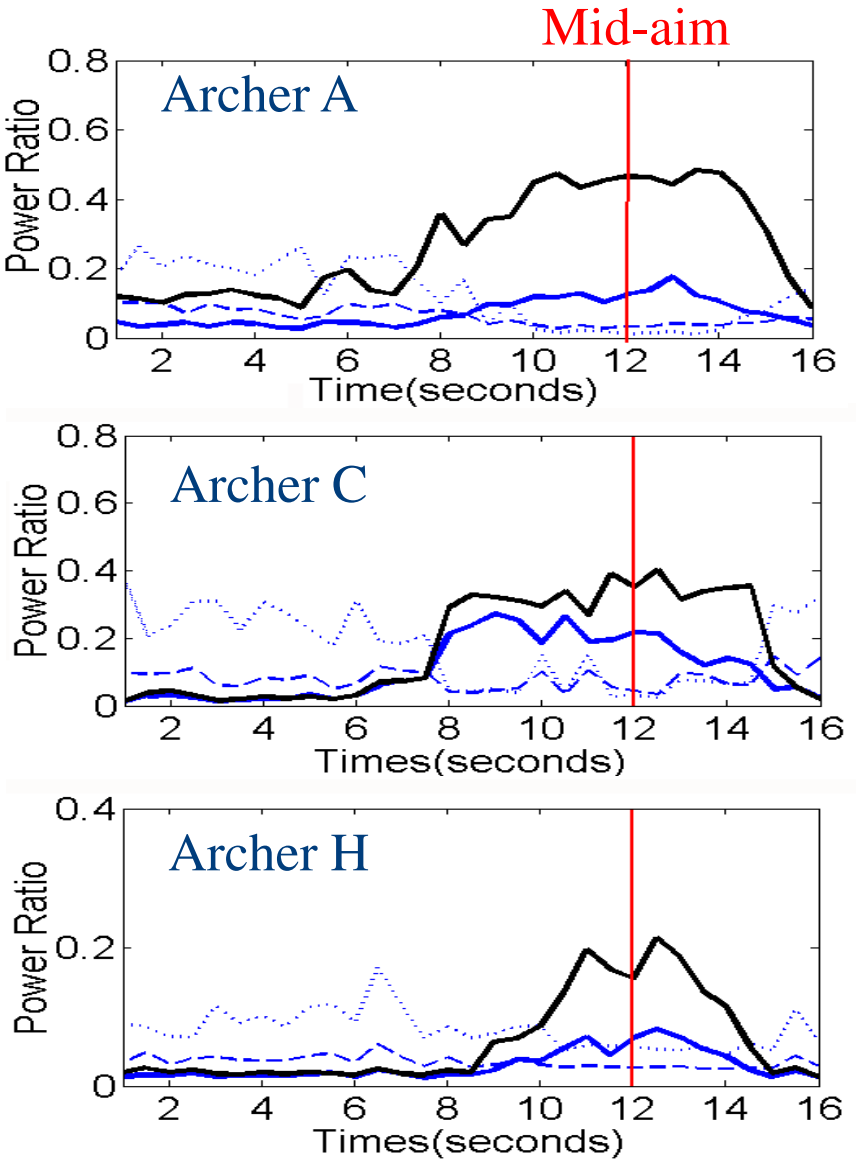
Results similar for same archer, different shots



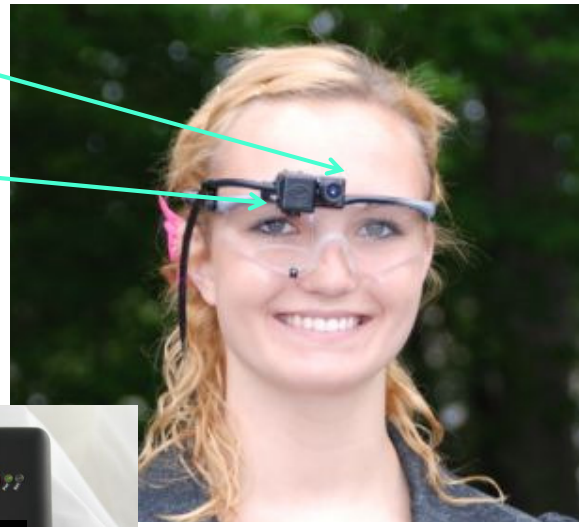
Archer A = Near-elite, right handed, male
Archer C = Elite, left-handed, female
Archer H = Right-handed, male



Results different between archers

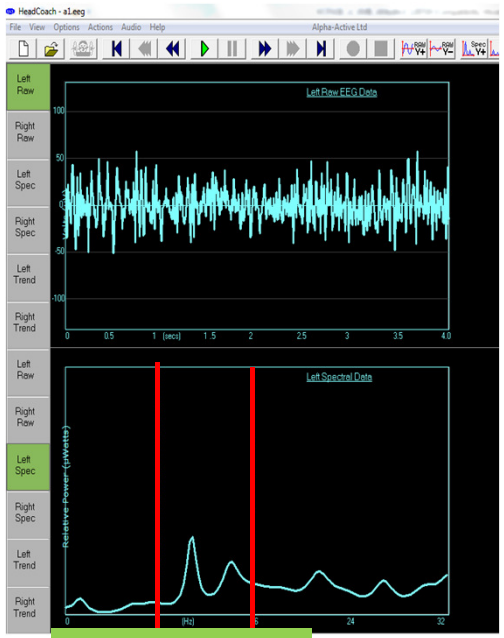


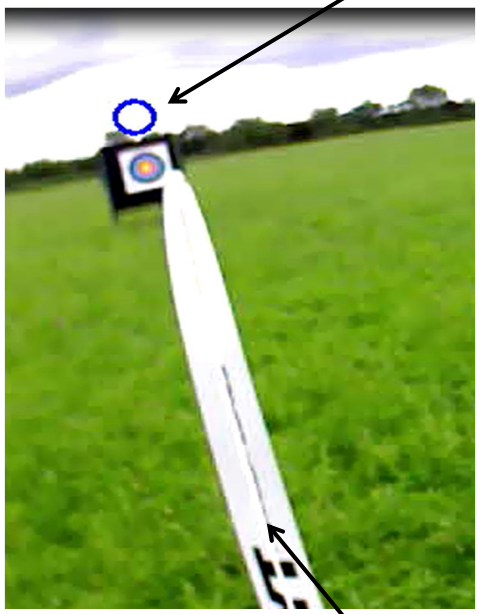
Wireless Mobile Eye-Tracker



- Accuracy of better than +/- 0.5 degrees
- High Resolution 2 megapixel scene camera
- Wireless range of 80 meters
- Calibration through scene image, no IR markers necessary
- 60Hz eye camera

Synchronous EEG and Eye-Tracker





- EEG and Eye-tracker output shown for the same time
- Archer is visually engaging with target ahead of taking aim
- EEG GUI shows a period of minimisation of eye movement and increased level of alpha waves

Conclusions

- Compact EEG can be used in ‘real-world’ practical sports studies
- There are distinct measurable changes in EEG patterns during each archery shot
- Average EEG shot profile can be established for an individual archer
- EEG profile varies from one archer to another, even for those of similar ability, but better archers have more consistent profile from shot to shot
- Initial comparisons of EEG profiles prior to arrow release do not show direct correlation to archery score metrology
- Eye-tracking & EEG indicate a period of ‘quiet eye’ before arrow is released

Further work

- Further evaluation needed to confirm and quantify conclusions
  - Across more sessions for a single archer
  - Across a wider range of experience
  - To explore individual shot performance more quantitatively by use of scatter diagrams [3]
  - To study in more detail the effects of eye & muscle movement on EEG spectrum
  - To explore further methods of data analysis
  - To determine if real-time feedback can be given and the best method for doing this (e.g. sound, physical stimulus, etc.)
- Work in progress in golf, motorsport, football, etc.
- Further comparison of EEG with simultaneous eye-tracking

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References

[1] Electroencephalographic Studies of Skilled Psychomotor Performance, *Bradley D. Hatfield, Amy J. Haufler, Tsung-Min Hung, and Thomas W. Spalding, Journal of Clinical Neurophysiology, Volume 21, Number 3, June 2004, 144-156.*

[2] Recent Advances in EEG Monitoring For General Anaesthesia, Altered States of Consciousness and Sports Performance Science, *M. J. Griffiths, P. Grainger, M.V. Cox, and A.W. Preece, 3rd IEE International Seminar on Medical Applications of Signal Processing, 3-4 November 2005, ISBN 0-86341-570-9/9-78086341-415708*

[3] Inter-Rater Reliability and Criterion Validity of Scatter Diagrams as an Input Method for Marksmanship Analysis: Computerised Notational Analysis for Archery, *Andrew J. Callaway and Shelley A. Broomfield, International Journal of Performance Analysis in Sport 2012, 12, 291-310.*

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Thank you

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