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\textsuperscript{[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
Combined EEG and Eye-tracking in sports training & analysis

Key characteristics of EEG spectrum

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

Spectrum (frequency domain) signal, left hemisphere

Raw (time domain) signal, left hemisphere

Arrow release time

Draw stage

Aiming stage
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

Mid-aim

Archer C: shot 3

Archer C: shot 5

Archer A

Archer C

Archer H
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

Thank you

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