Effect of Feedback Type and Training on Voluntary Control of Single Motor Units

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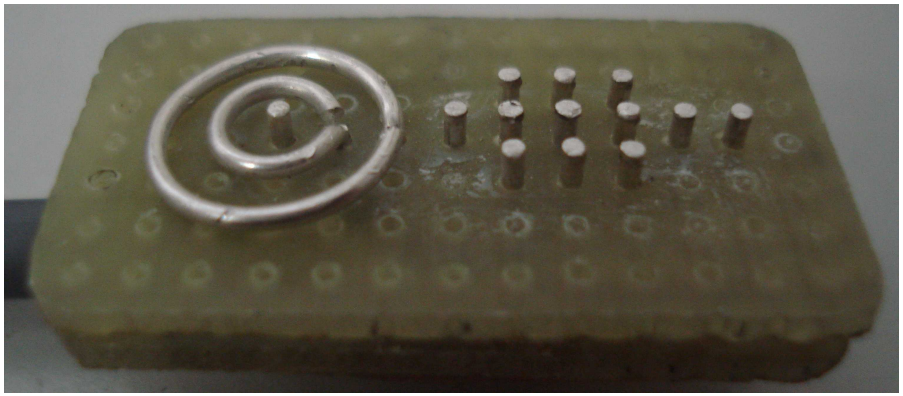
Control Of Motor Units

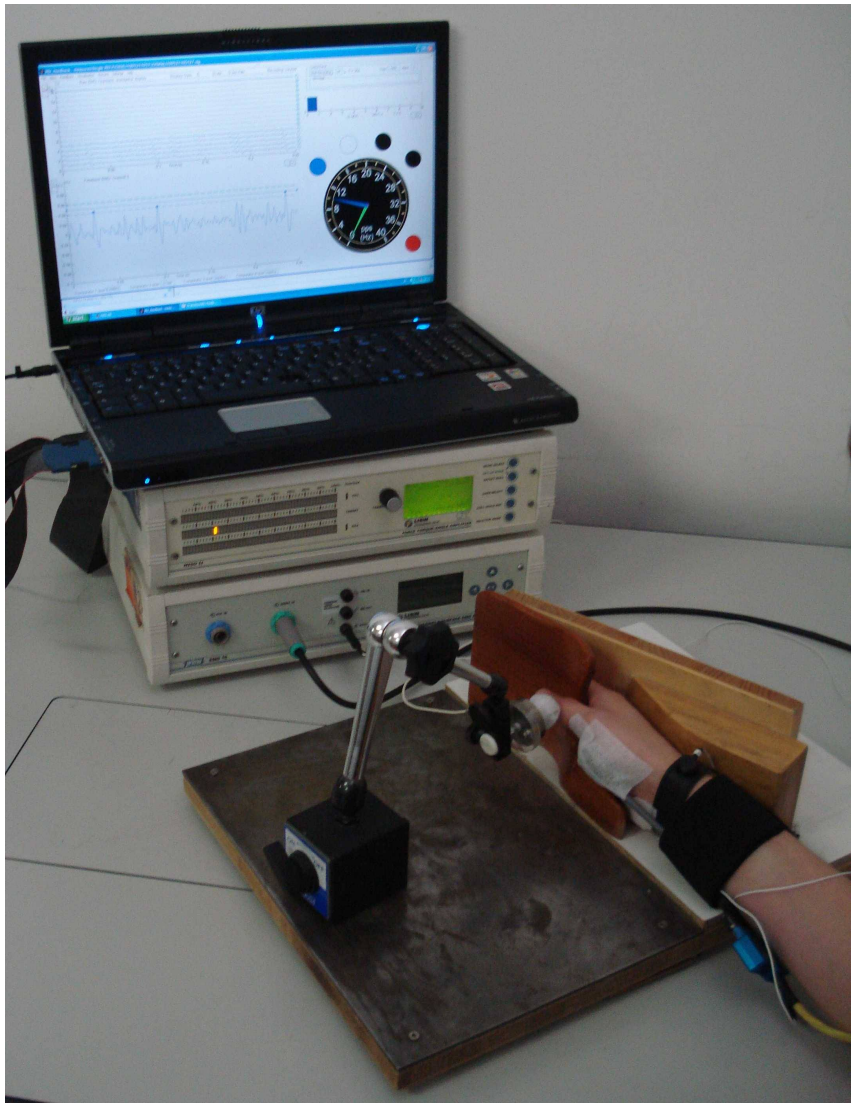
- Control over an individual motor unit's (MU) activation and firing rate has been demonstrated by Basmajian (1963) with needle EMG
- Humans naturally control force, not MUs
- Learning MU control is possible with feedback

Questions?

- Can a subject control a single MUs activation and firing rate when provided with feedback from **surface** EMG signals?
- How do the feedback methods compare?

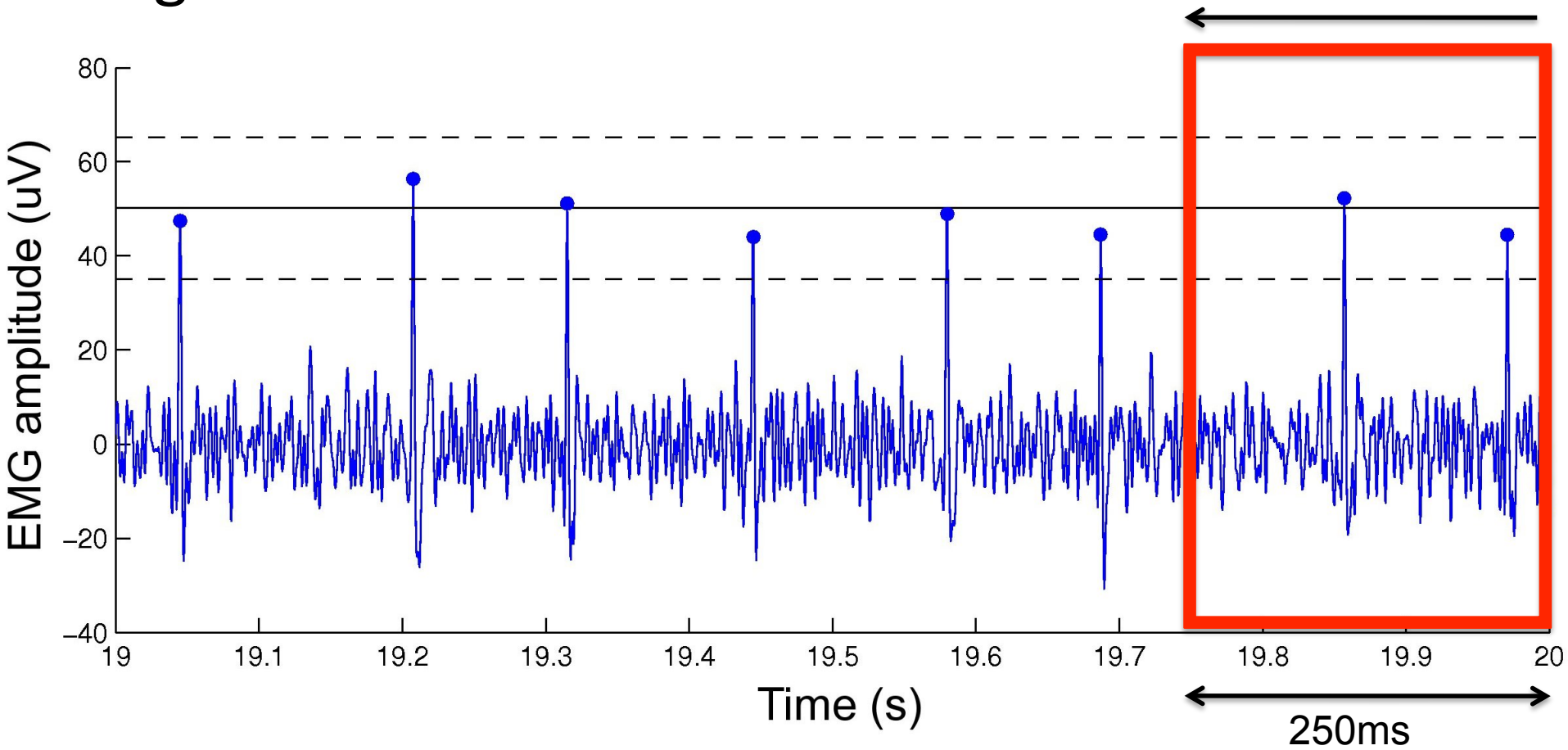
Apparatus



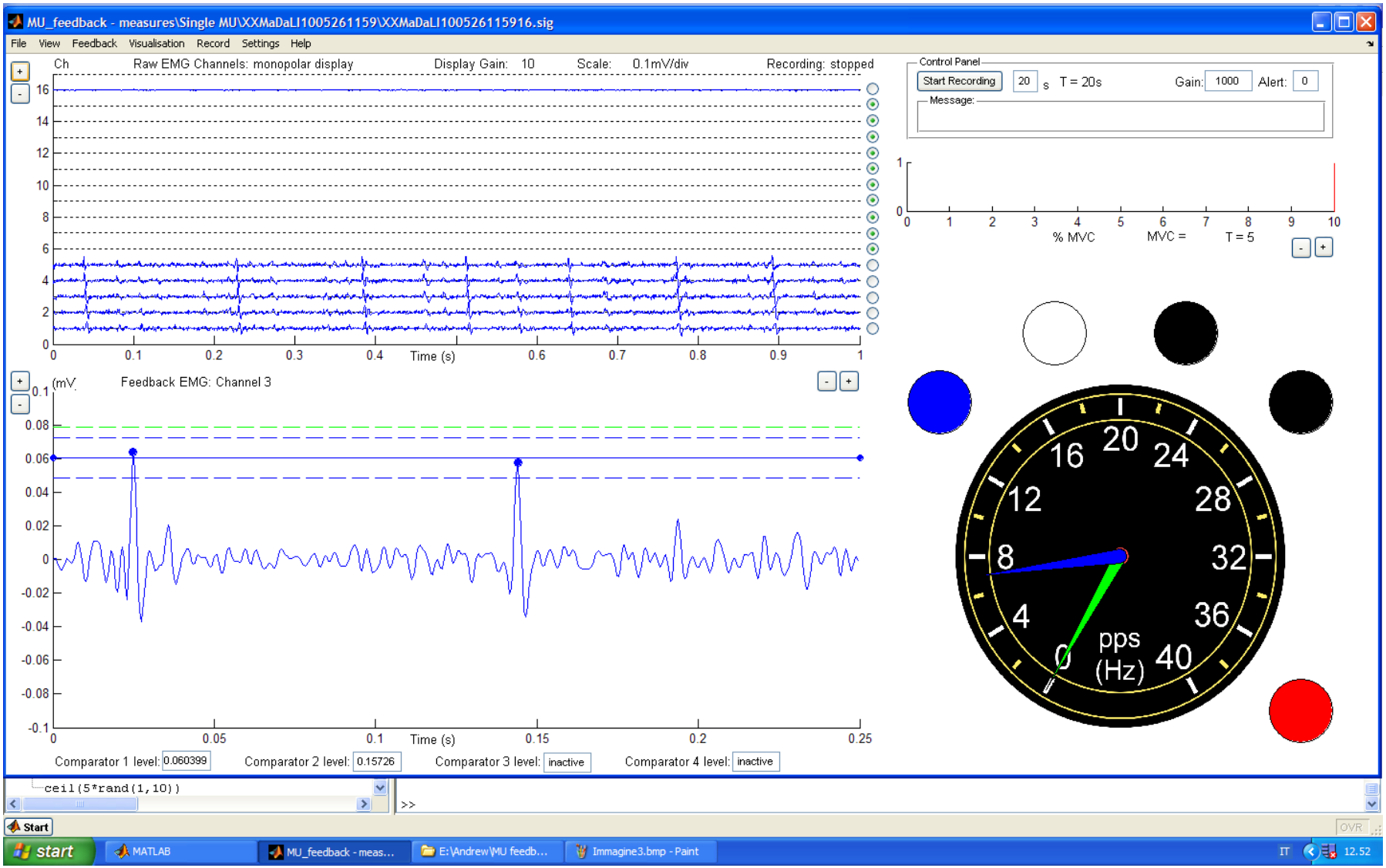


Feedback

- Linear double differential (LDD) Feedback signal

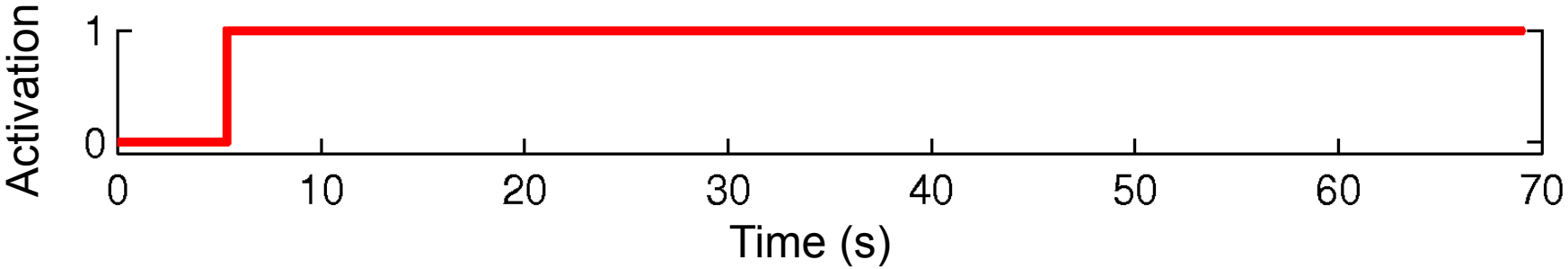


MU Feedback GUI

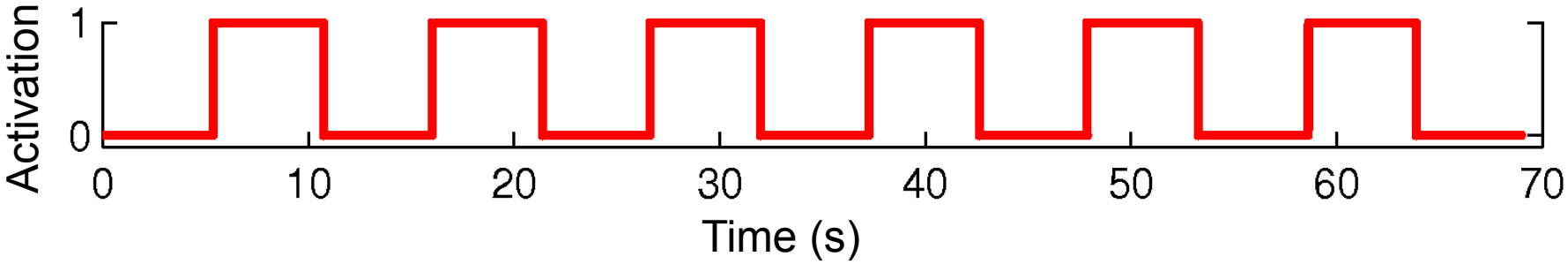


MU Control Tests

C1: Activate and isolate a single MU for 60s

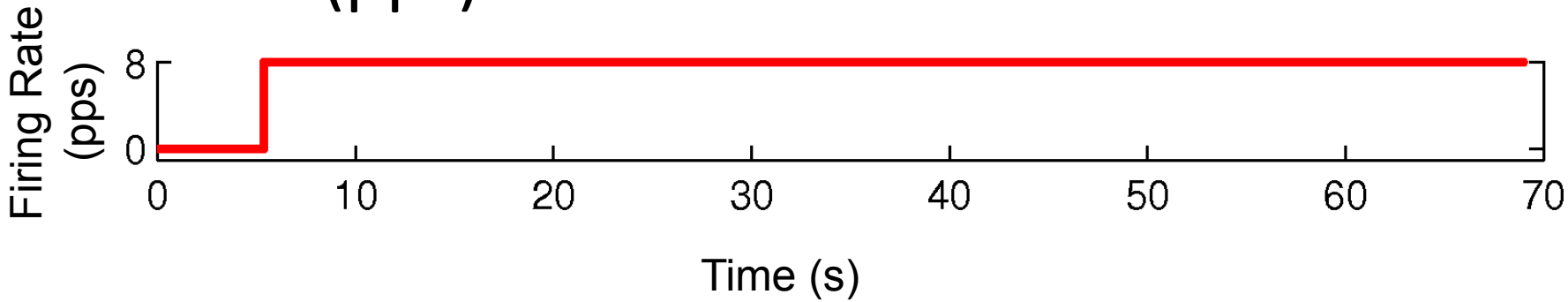


C2: Activate and deactivate that MU every 5s for 60s

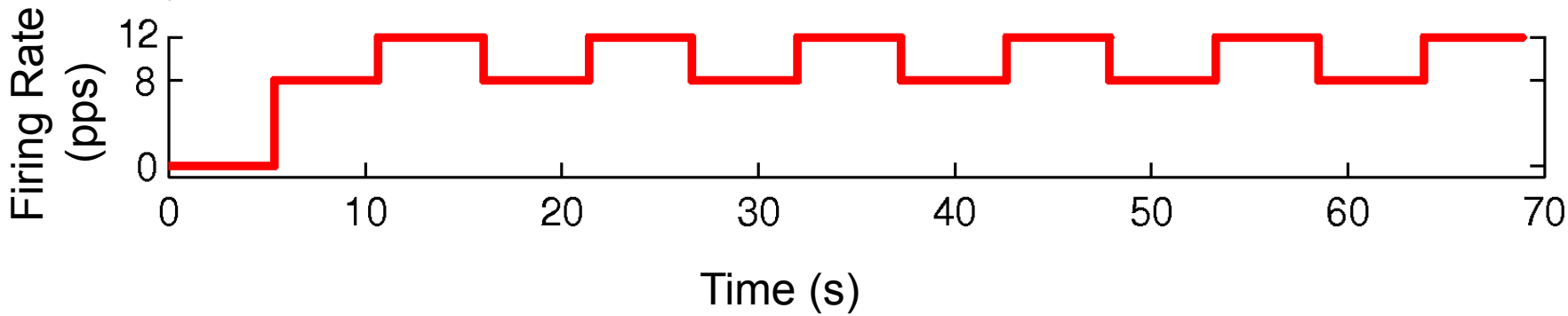


MU Control Tests

C3: Maintain the MU's firing rate at 8 pulses per second (pps) for 60s

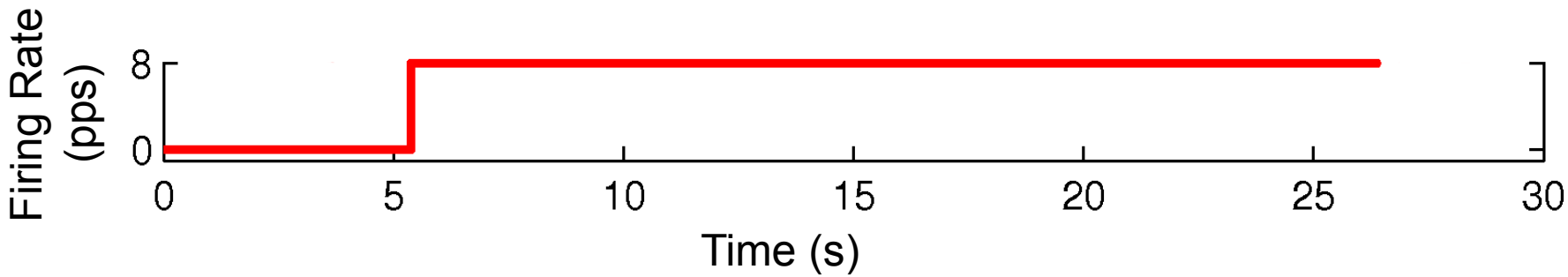


C4: Modulate the firing rate of the MU between 8 and 12pps every 5s for 60s



Feedback Tests

- Maintain a firing rate of 8 pps for 20s (i.e. C3)
  - F1: All feedback
  - F2: Only audio
  - F3: Only firing rate speedometer
  - F4: Only raw EMG signals
  - F5: No feedback



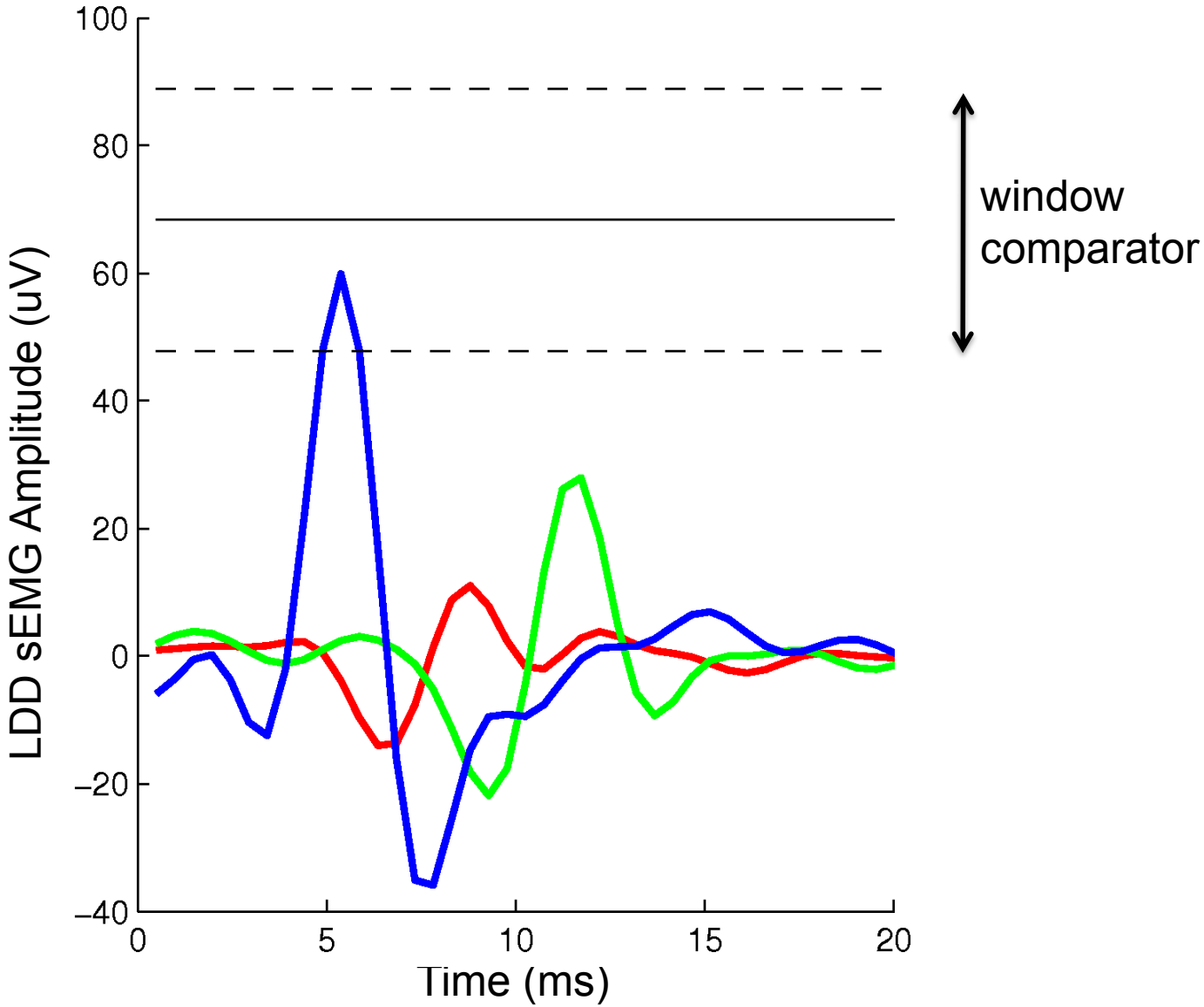
Training

- Two 15 minute training sessions
- All feedback provided
- Subjects verbally instructed on single MU control techniques
  - encouraged when performance is good
  - discouraged when performance is bad
- Encouraged to practice the four MU control tests

sEMG Signal Decomposition

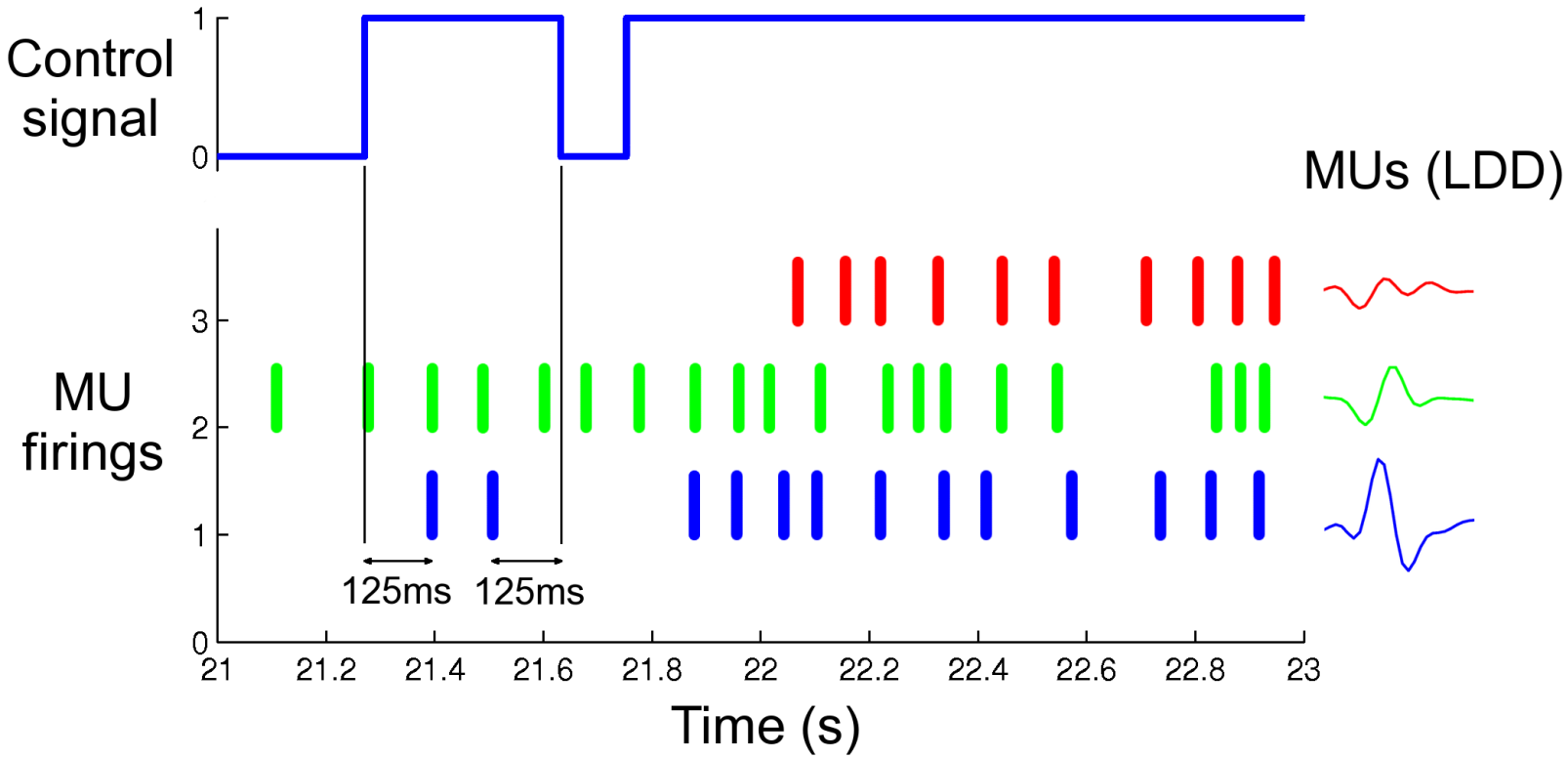
- Off-line decomposition: Convolution Kernel Compensation (CKC) Algorithm of Holobar and Zazula (2007)
- Firing patterns of identifiable MUs used to extract MU templates

Controlled MU



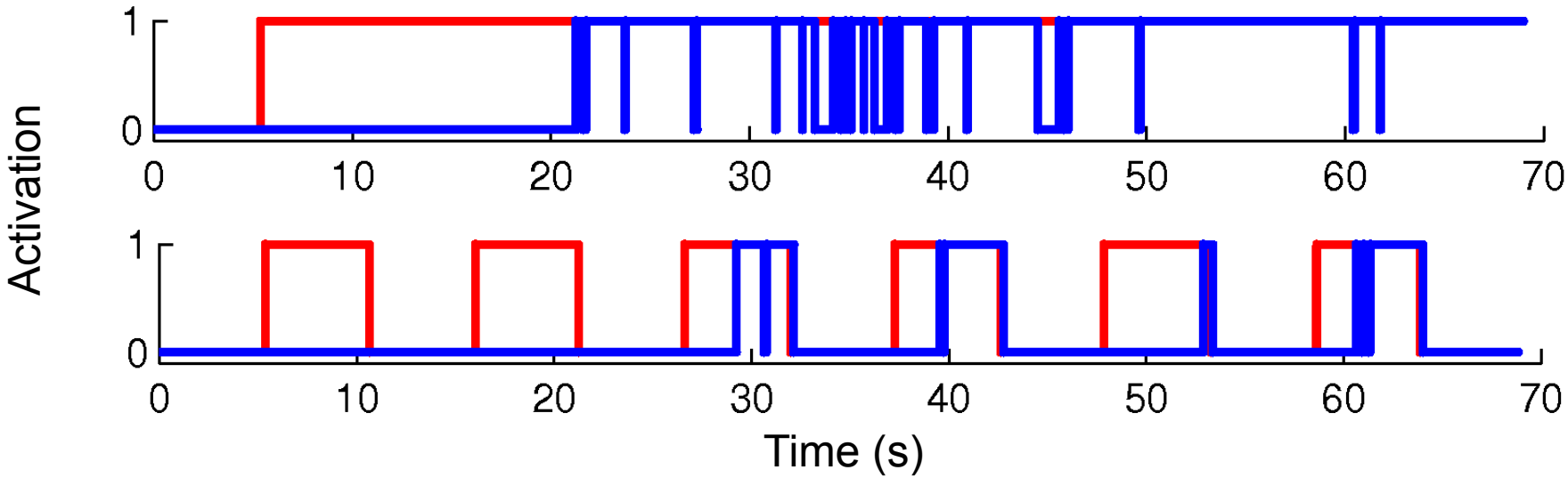
Evaluation of MU activation control

- Firing pattern used to extract control signal



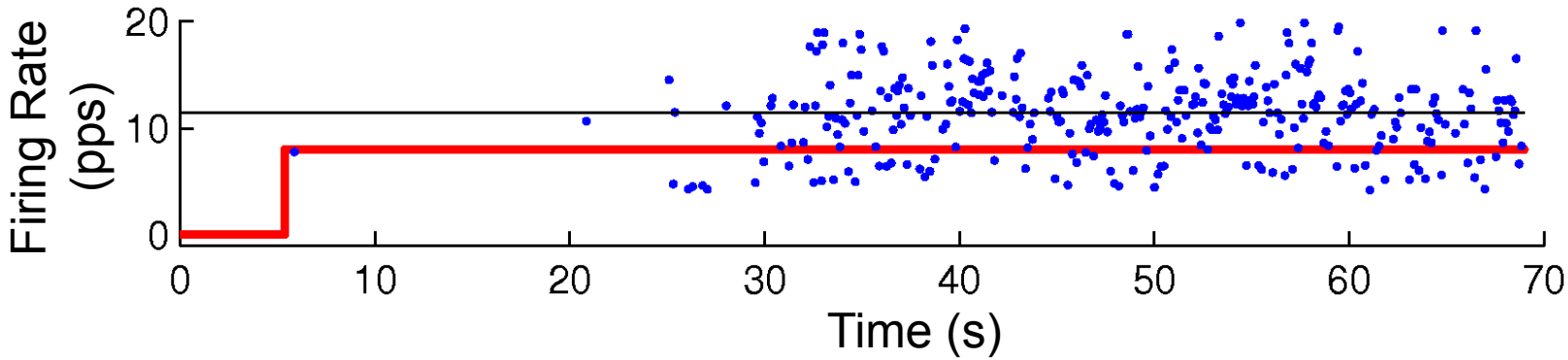
Evaluation of MU activation control

- Performance Indicator (PI) = mean squared error (MSE) between target (red) and control (blue) signals
  - $PIa = mean(S_{Target} - S_{Control})^2$



Evaluation of MU firing rate control

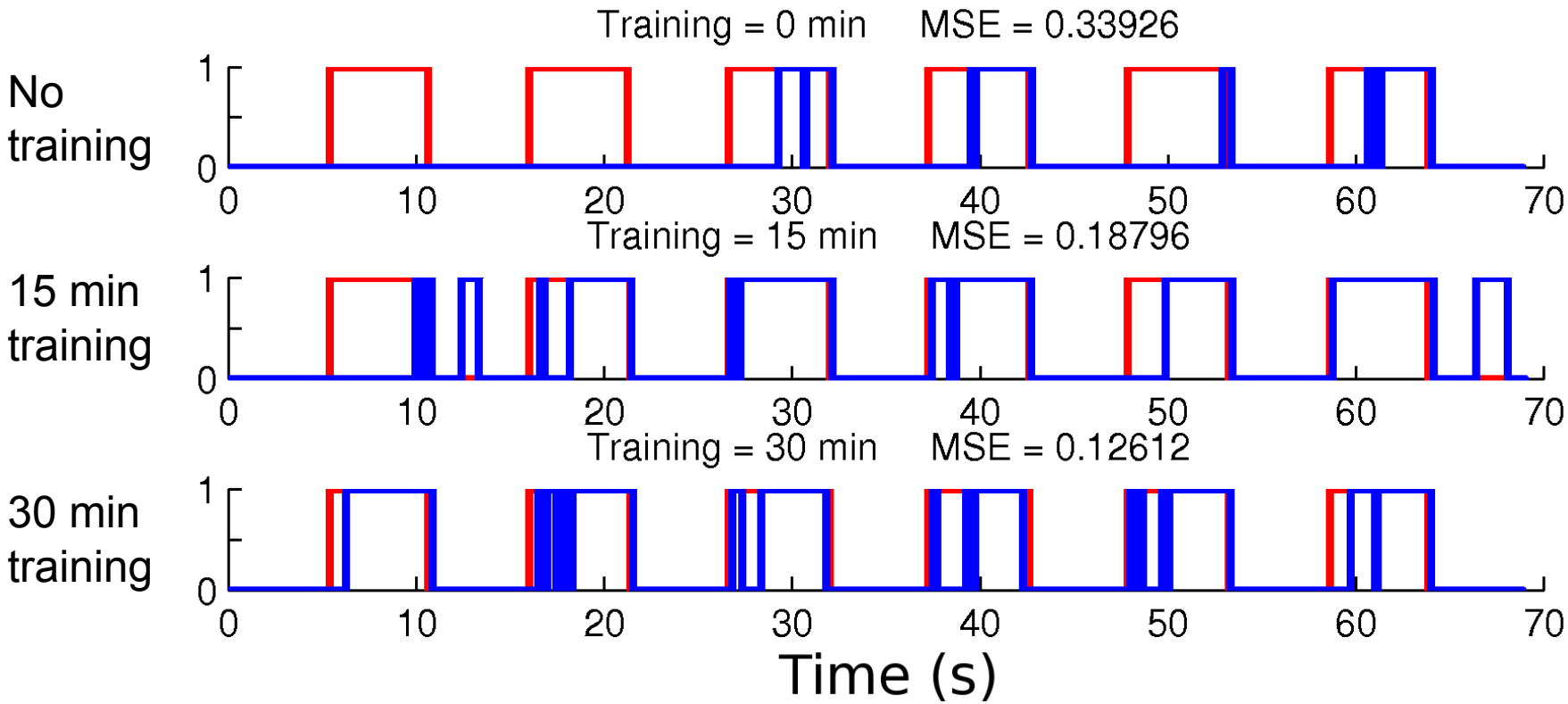
- Instantaneous firing rate (IFR) used to evaluate performance
- accuracy: IFR mean
  - $PI_{fr1} = ((mean(IFR) - S_{Target})/S_{Target})^2$
- precision: IFR variance
  - $PI_{fr2} = var(IFR)/S_{Target}$



Results

- Contraction levels: 0.6 ± 0.75 %MVC
- Always below 2.5 %MVC
- Initially subjects struggled to isolate a single MU
- Improvement with training
  - reduced MSE
  - increased accuracy: mean closer to target
  - increased precision: decreased variance

Training Improvements

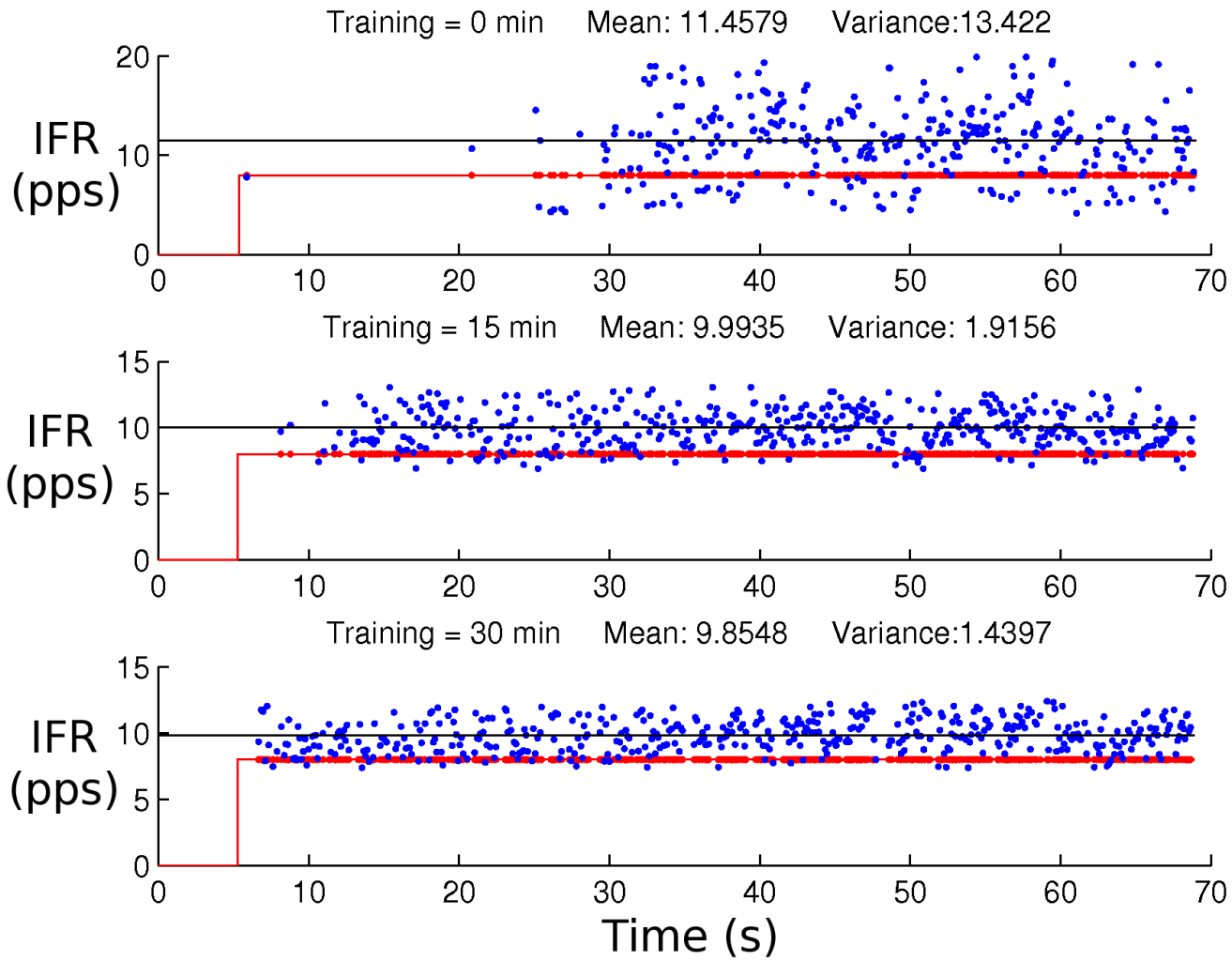


Training Improvements

No training

15 min training

30 min training



Results

- Preferred feedback
  - MU peak audio beeps
  - Firing rate speedometer
- Subjects found raw sEMG feedback to be confusing
- Further statistical analysis needed to prove significance

Conclusion

- Individuals show the ability to learn control over activation and firing rate of a single MU from **surface** EMG feedback
- The simplest forms of feedback seem to be the most useful forms of feedback for subjects inexperienced in EMG

Direct audio and visual indication of MU features seems to provide the best feedback

Acknowledgements

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- Politecnico di Torino, Italy

References

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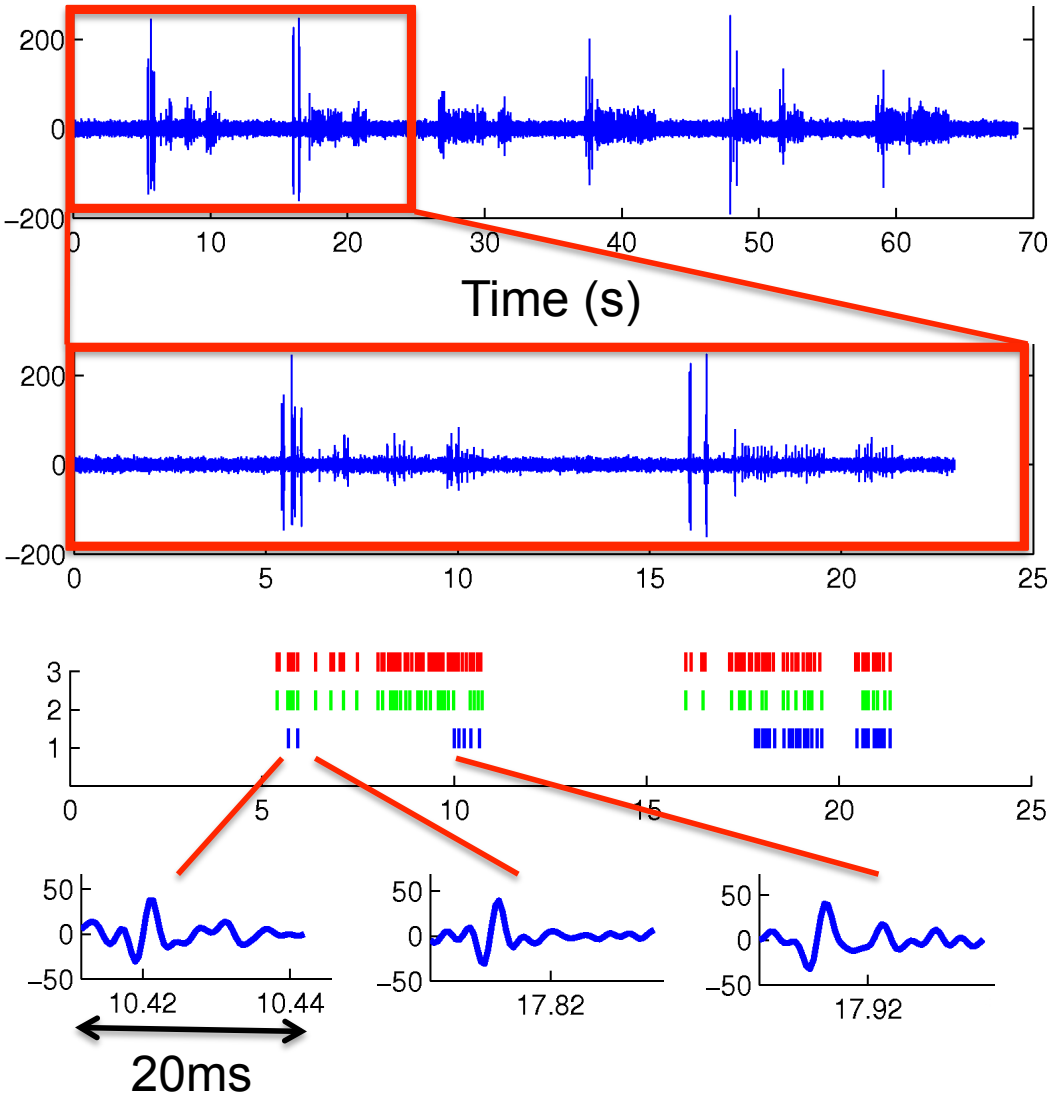
MU Template Extraction

feedback EMG signal (uV)

1st averaging window

firing patterns of identified MUs

windows of 30ms centered at each MU firing



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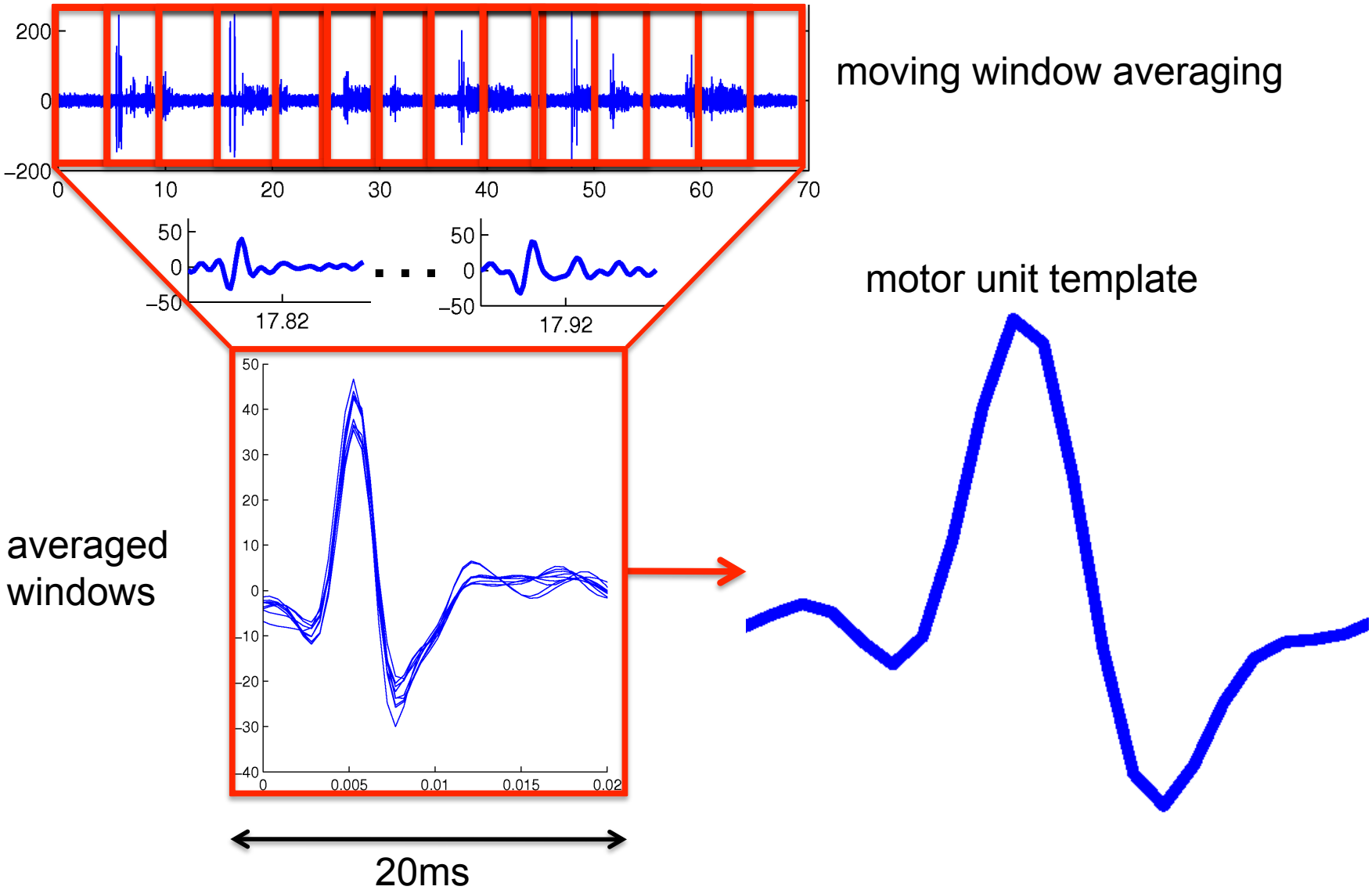

Testing Protocol

- Sixteen healthy volunteers
  - age: 24 ± 2.37 years (mean ± S.D)
  - height: 1.77 ± 0.09 m
  - weight: 67.9 ± 11.8 kg
- Isometric contractions of abductor pollicis brevis (APB) muscle
- Below 2.5% MVC

Apparatus

- Load cell
- 15 channel electrode grid
  - 1 mm silver electrodes
  - 2.5 mm inter-electrode distance (IED)
- Single Differential (SD) sEMG
- Multichannel EMG amplifier (EMG-16, OT Bioelettronica)

Feedback

- Visual feedback
  - Raw EMG signals (Single Differential)
  - Feedback Signal (Double Differential)
  - Window comparator
  - Firing rate speedometer
- Audio feedback
  - High tone beep when a peak is detected
  - Low tone beep when peak is above comparator window