

# Introduction to EMG Decomposition

Kevin McGill  
Ted Clancy  
Zoia Lateva  
Dan Stashuk  
Ales Holobar

*National Institute of Neurological  
Disorders and Stroke  
US National Institutes of Health*

## Introduction to EMG Decomposition

- Kevin McGill Overview
  - Technical issues
  - EMGLab: Open-source decomposition program
- Zoia Lateva Strategies for manual decomposition
- Ted Clancy Working together: EMG decomposition user's group
- Dan Stashuk Decomposition-based quantitative clinical EMG
- Ales Holobar Decomposition of high-density surface EMG
- Kevin McGill How accurate is this decomposition?

### The muscle

**Muscle cross section** (50 μm scale bar)

**Muscle architecture**: parallel, unipennate, bipennate

Labels: bone, muscle fibers, tendon, aponeurosis

### The motor unit

Labels: alpha motoneuron, nerve impulse, motor endplates, muscle fibers, motor-unit territory

### The motor-unit action potential (MUAP)

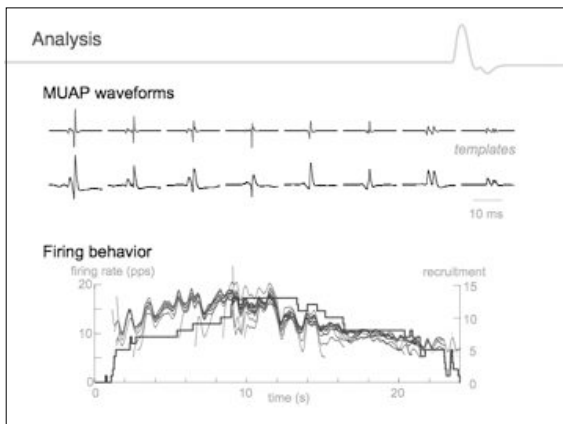
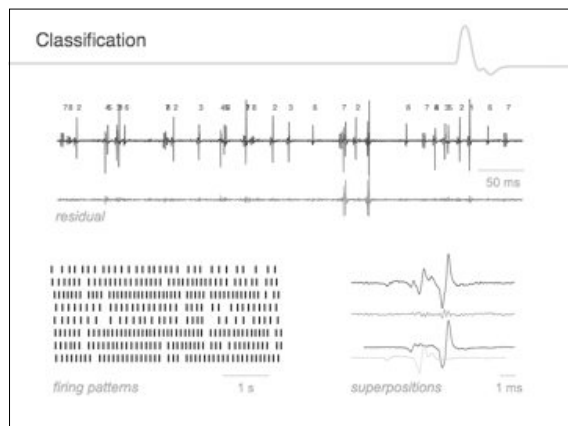
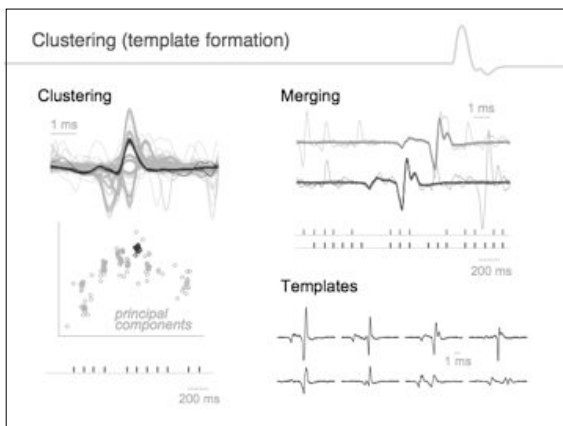
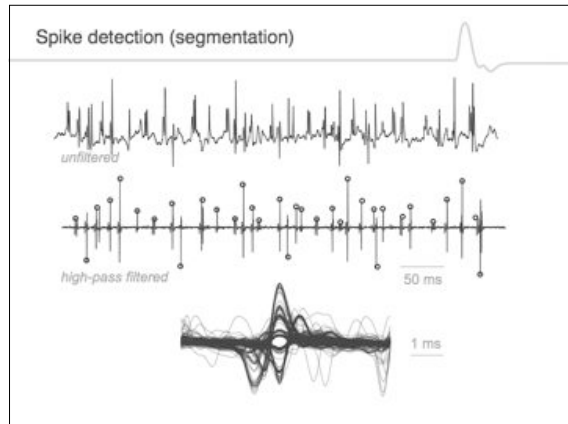
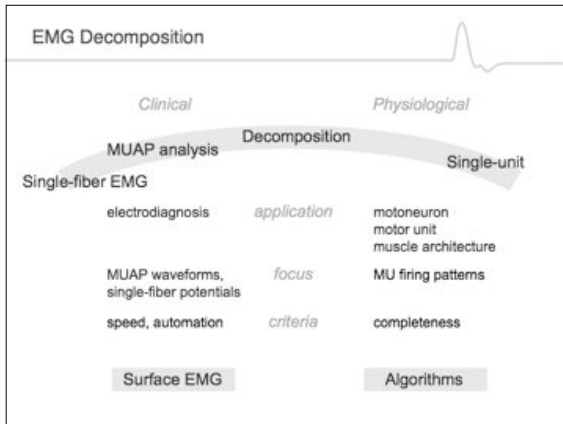
Labels: MUAP

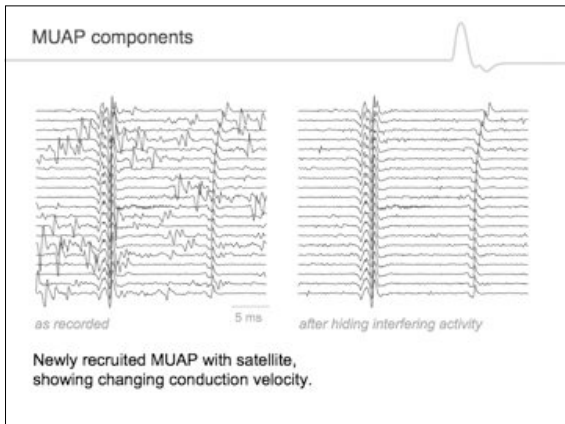
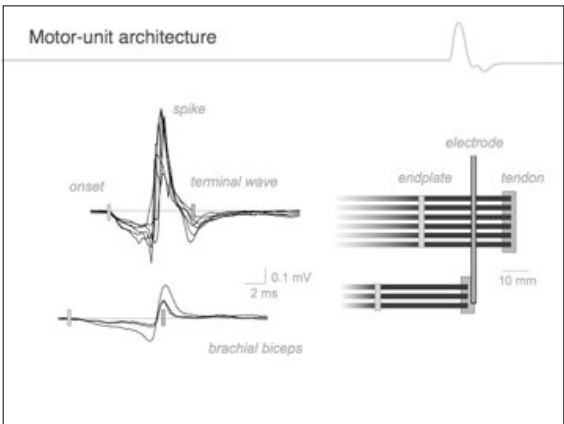
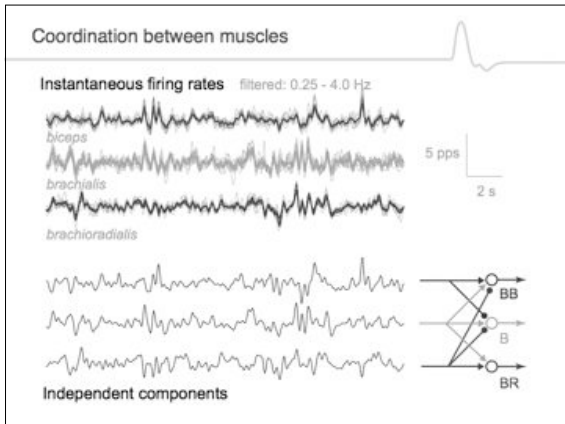
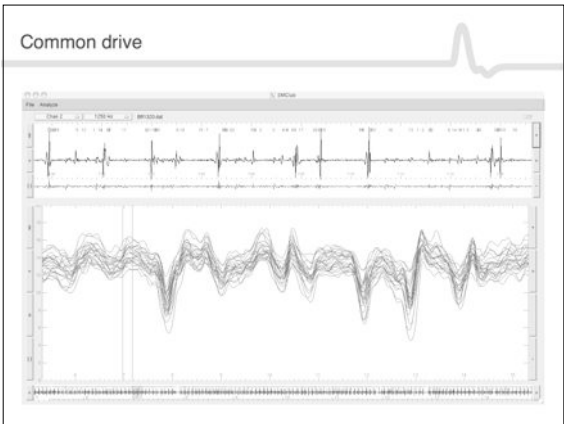
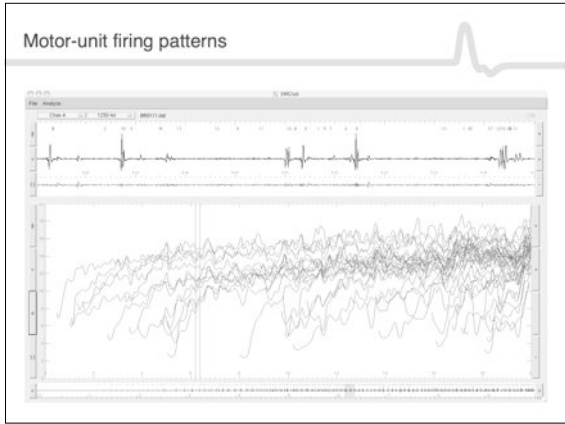
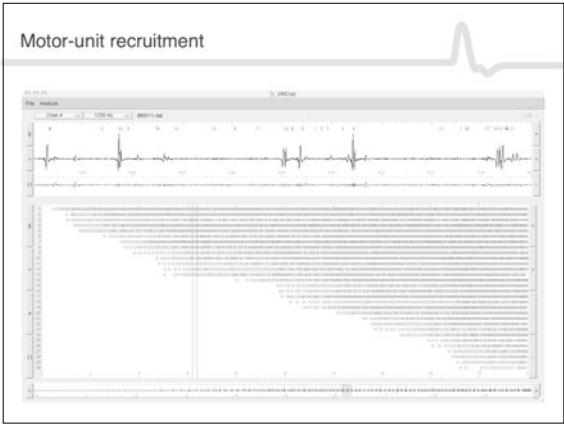
Scale: 200 μV, 5 ms

### The electromyogram (EMG)

Labels: MUAP trains, high-pass filtering, composite EMG signal (interference pattern)

Scale: 10 ms, 50 ms, 2 s





http://www.emglab.net

**EMGLAB**  
A forum for sharing software, data, and information related to EMG decomposition.

EMG decomposition provides information about the coordinated activity of the neuromuscular system and the architectural organization of the muscle. The development of methods to handle growing data sets, knowledge, and clinical neurophysiology.

The goal of this project is to provide:

- decomposition as a research tool
- exchange and discussion of EMG data
- attention to accuracy
- algorithm innovation

Projects: Standards for data files, EMG signal databases, recording hardware, EMG analysis software.

Software: EMG simulator software, EMG decomposition, EMG decomposition toolbox, EMG Lab GUI, EMG.

News: EMG decomposition, EMG decomposition toolbox, EMG Lab GUI, EMG.

Publications: EMG decomposition toolbox, EMG decomposition toolbox, EMG Lab GUI, EMG.

EMGLab database

**Signals**

**Brain signals**

- 0001: Myoelectric signals, isometric contraction
- 0002: Needs and low work, isometric contraction
- 0003: Coactivation needs, isometric contraction
- 0004: Quadriceps needs, isometric contraction
- 0005: Myoelectric signals, isometric contraction
- 0006: Myoelectric signals, isometric contraction
- 0007: Free work, isometric contraction
- 0008: Multi-channel free work, isometric contraction
- 0009: Quadriceps needs, isometric contraction

**Typical signals**

- 0010: Simulated EMG
- 0011: Simulated EMG
- 0012: Simulated pathological EMG

**Database**

- 0013: Database of clinical signals

- Sample signals from nine institutions.
- Illustrate different recording techniques
  - muscles
  - experimental conditions
- Dataset of clinical signals (Nikolic, 2001).

Database of clinical signals

**N2001**

Database of clinical signals, Nikolic, M, Biphosphatid, Copenhagen, DK. (2001)

Subjects: 1001, 1002, 1003, 1004, 1005, 1006, 1007, 1008, 1009, 1010, 1011, 1012, 1013, 1014, 1015, 1016, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1028, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1043, 1044, 1045, 1046, 1047, 1048, 1049, 1050, 1051, 1052, 1053, 1054, 1055, 1056, 1057, 1058, 1059, 1060, 1061, 1062, 1063, 1064, 1065, 1066, 1067, 1068, 1069, 1070, 1071, 1072, 1073, 1074, 1075, 1076, 1077, 1078, 1079, 1080, 1081, 1082, 1083, 1084, 1085, 1086, 1087, 1088, 1089, 1090, 1091, 1092, 1093, 1094, 1095, 1096, 1097, 1098, 1099, 1100, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1109, 1110, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1118, 1119, 1120, 1121, 1122, 1123, 1124, 1125, 1126, 1127, 1128, 1129, 1130, 1131, 1132, 1133, 1134, 1135, 1136, 1137, 1138, 1139, 1140, 1141, 1142, 1143, 1144, 1145, 1146, 1147, 1148, 1149, 1150, 1151, 1152, 1153, 1154, 1155, 1156, 1157, 1158, 1159, 1160, 1161, 1162, 1163, 1164, 1165, 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1996, 1997, 1998, 1999, 2000, 2001.

Waveform plot showing signal amplitude over time.

- over 1000 signals from 30 subjects
  - myopathy
  - ALS
  - normal controls

EMGLab software

**Software**

**EMGLAB v 0.9**

EMGLAB is a Matlab program for analyzing EMG signals. It implements a number of algorithms for processing EMG signals, including:
 

- decomposition of EMG signals into individual motor unit potentials (MUPs)
- detection of MUPs in noisy signals
- classification of MUPs into different motor unit types
- estimation of MUP parameters (amplitude, duration, rise time, etc.)
- simulation of EMG signals
- visualization of EMG signals and MUPs

**MTLEMS**

MTLEMS (Muscle Tone Linear Estimation Method) is a multi-channel decomposition algorithm by Havelka and Nikolic. It includes a genetic algorithm for finding superpositions. The Matlab package will be used as a model decomposition, or as a plug-in for EMGLAB.

**EMG Simulator**

A package for simulating normal and pathological EMG signals for teaching, research and clinical use. The package contains extensive documentation for the PC and non-Matlab users and a user interface written in Matlab.

**EMG Amplitude Estimation Toolbox**

A Matlab toolbox for EMG amplitude estimation using single or multiple channels of EMG, with or without signal whitening.

Electrodes

**Less selective**

- concentric needle
- monopolar needle
- fine-wire

**Selective**

- quadrifilar needle
- quadrifilar wire
- cut-end wire

1 mm

Electrodes

**Less selective electrode**

- contacts more fibers
- averages potential field over larger extent

**potential field**

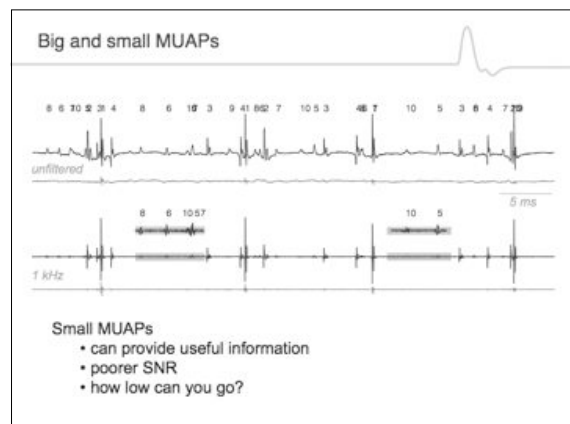
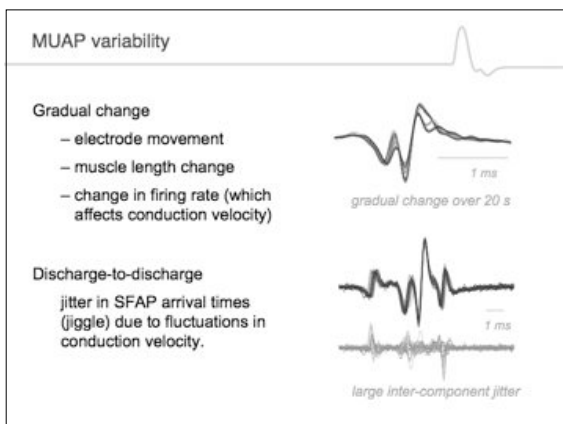
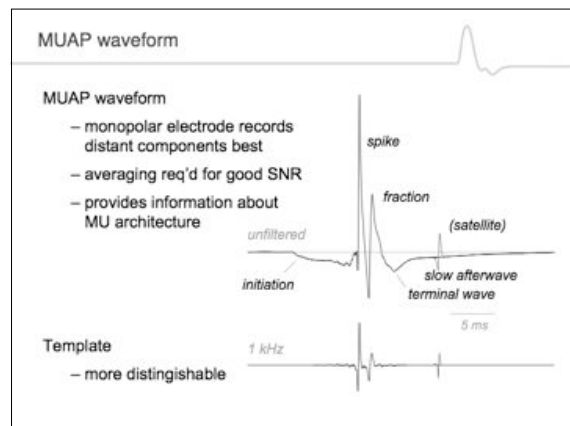
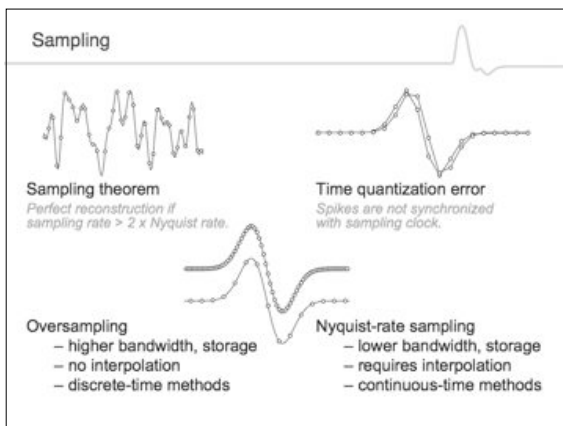
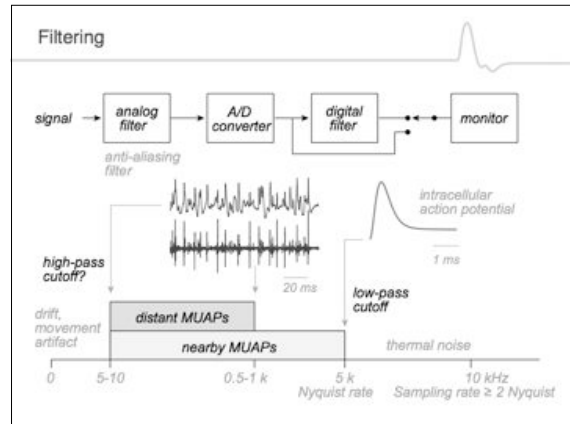
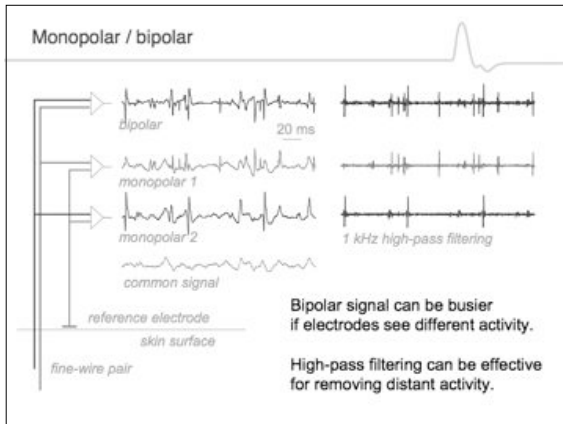
**recorded action potentials**

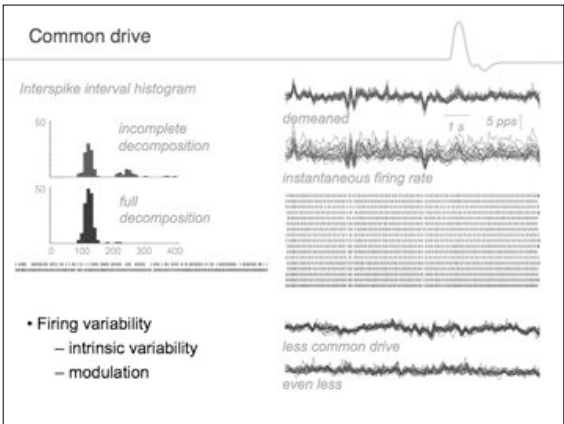
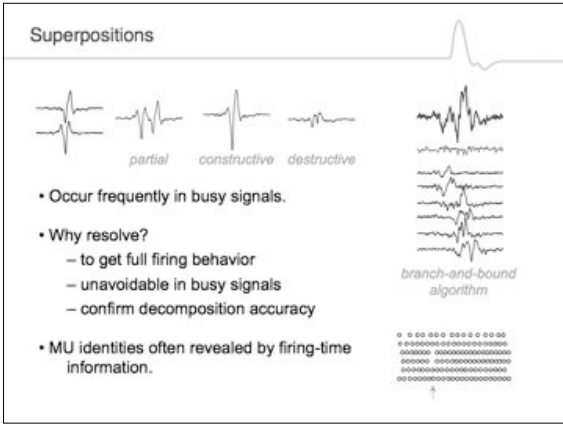
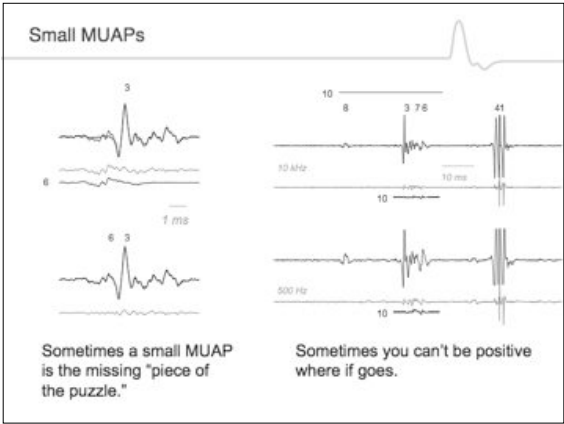
50  $\mu$ m

1 ms

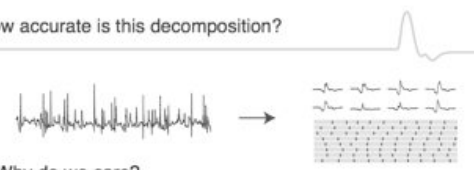
**Selective electrode**

- contacts fewer fibers
- averages potential field over smaller extent





### How accurate is this decomposition?




**Why do we care?**

- To be scientific.
- To save ourselves from wishful thinking.
- To convince others.

**What do we mean?**

- Accuracy of the algorithm?
- Accuracy of the signal?
- Accuracy of each MUAP train!



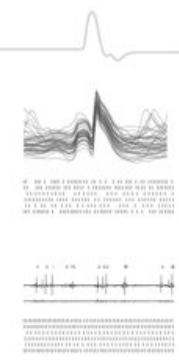
### Standards of evidence

**Burden of proof**

- MUAP validity, firing statistics
- Firing and recruitment patterns
- MUAP waveforms, precise firing times

**Desirable characteristics**

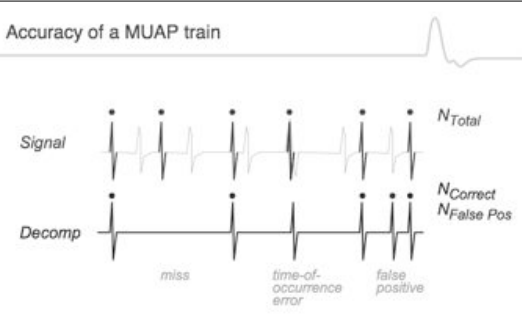
- Convincing
- Visual / Quantitative / Statistical
- Based on reasonable assumptions
- Practical to obtain



### Ways of assessing accuracy

- External evidence**
  - independent signals from same contraction ("two-source," "cross-checking")
- Internal evidence**
  - inter-algorithm / inter-operator consistency
  - physiological consistency
  - "seeing is believing"
  - a-posteriori probability
- Validation study**
  - simulated data
  - real data

### Accuracy of a MUAP train



$N_{Total}$

$N_{Correct}$

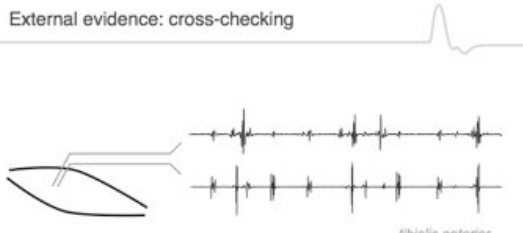
$N_{False Pos}$

miss      time-of-occurrence error      false positive

$$Accuracy = \frac{N_C}{N_T + N_F}$$

**Certainty vs Confidence**

### External evidence: cross-checking



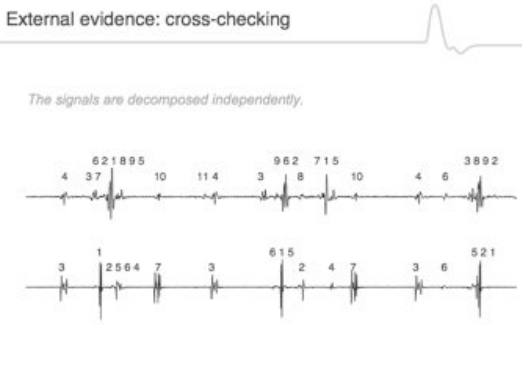
tibialis anterior

Signals are recorded simultaneously from nearby sites in the same muscle.

Some motor units will be seen in both channels.

### External evidence: cross-checking

The signals are decomposed independently.



6 2 1 8 9 5      10      11 4      3      9 6 2      7 1 5      10      4      6      3 8 9 2

3      1      2 5 6 4      7      3      6 1 5      2      4      7      3      6      5 2 1

