

Motion Browser: Visualizing and Understanding Complex Upper Limb Movement Under Obstetrical Brachial Plexus Injuries

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RUTGERS
New Jersey Medical School



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Childbirth "Arm Nerves"

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Agenda

Introduction

Tasks and Design

Case Study

Conclusion

Introduction

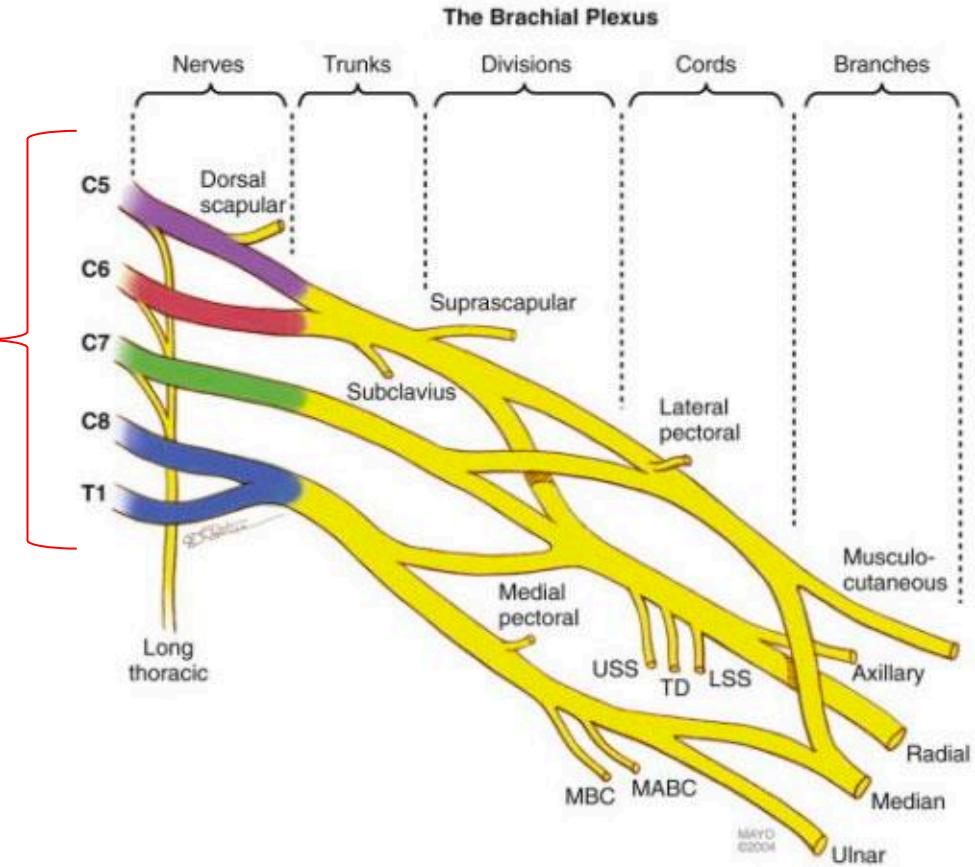
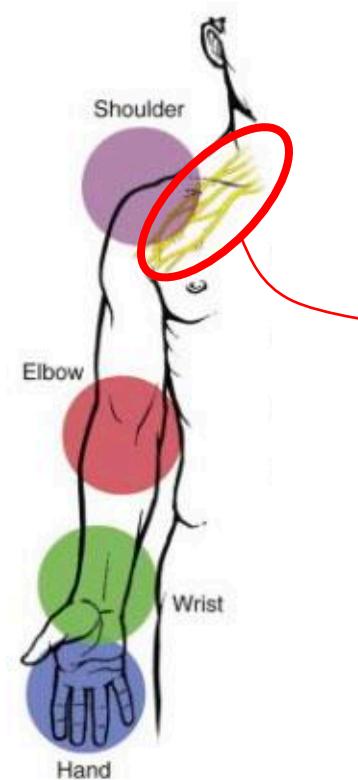
Introduction

Obstetrical Brachial Plexus Injuries

An injury to the nerves that control the muscles on the upper limb around the time of birth.

The brain will conduct some compensatory actions when some of the muscles cannot be used.

How does our brain coordinate the muscles under the injury are still not well studied.



Introduction

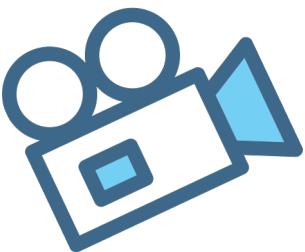
Active Range Of Motion Assessment

1

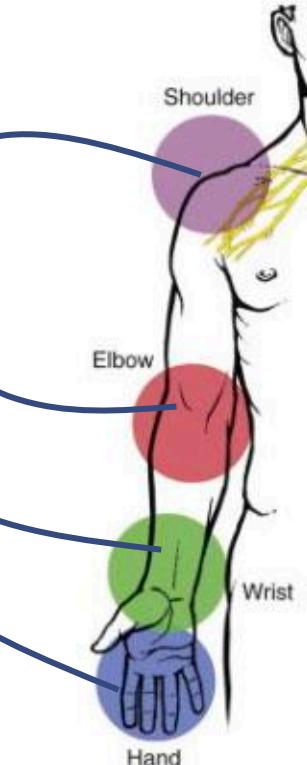
Electromyography (EMG) signals of muscle activations



2



Motion sensors recording limb displacement



3

Video recordings



Introduction

Active Range Of Motion Assessment

Active Range of Motion (AROM) dataset:

1

EMG signals of muscle activations

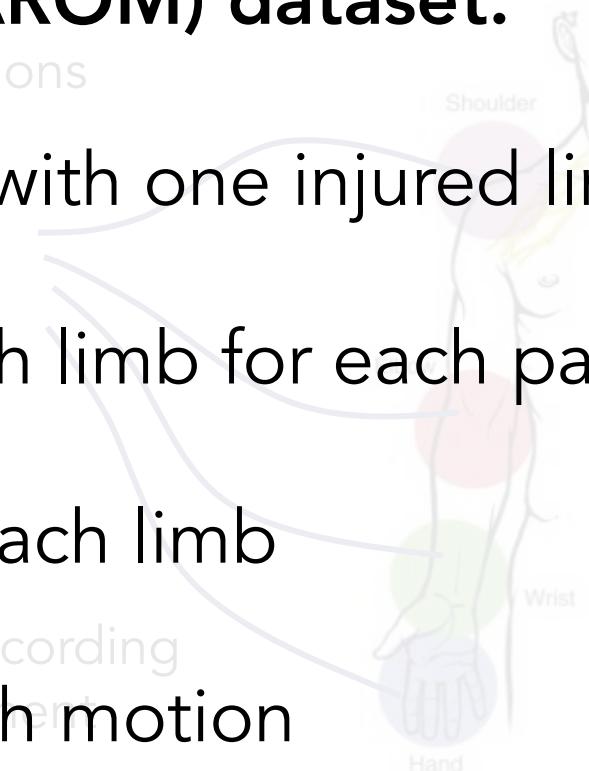
1. 8 patients in total (each with one injured limb)

2. 8 muscle sensors on each limb for each patient

3. 3D motion tracking on each limb

4.2 Video recordings on each motion

5. 16 motions (shoulder, elbow and wrist) performed by each patient



3

Video recordings

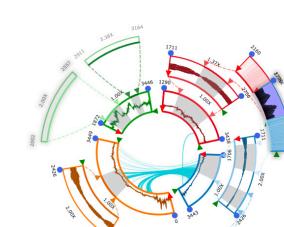


Introduction Challenges

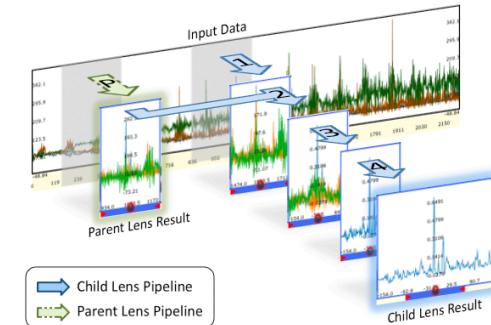
Comparing affected and unaffected limbs among all patients



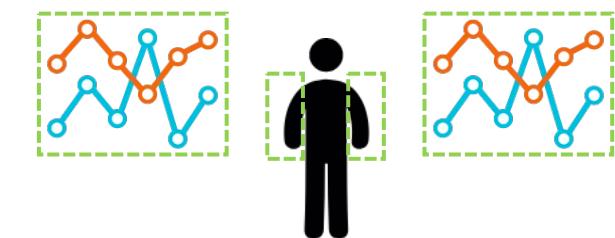
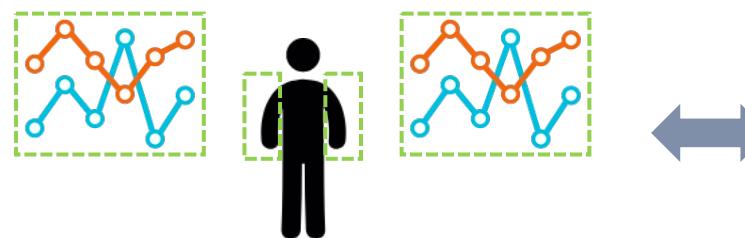
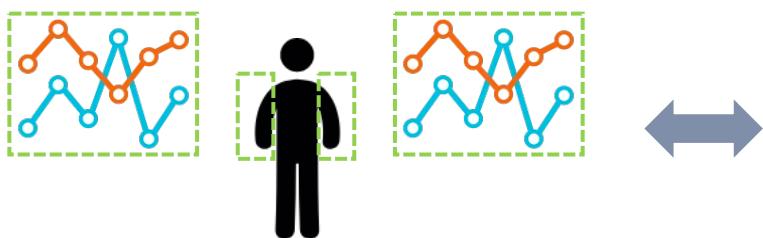
SignalLens TVCG 2010



Kronominer SIGCHI 2011

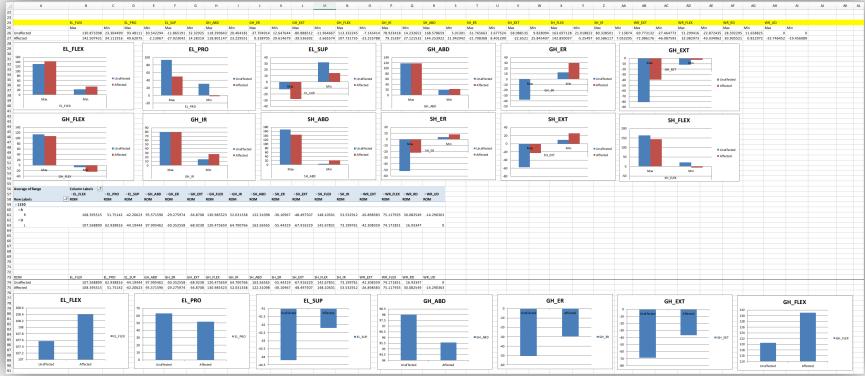


Chronolens TCG 2011



No effective techniques to visually compare multiple multivariate temporal muscle signals between different limbs.

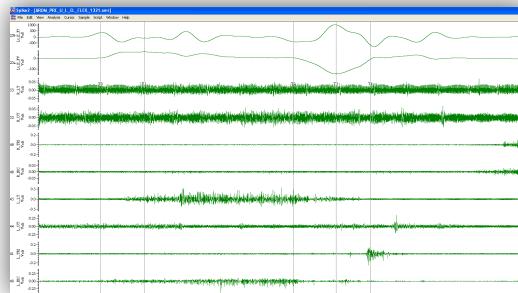
Introduction Challenges



Data
Analysis



Videos



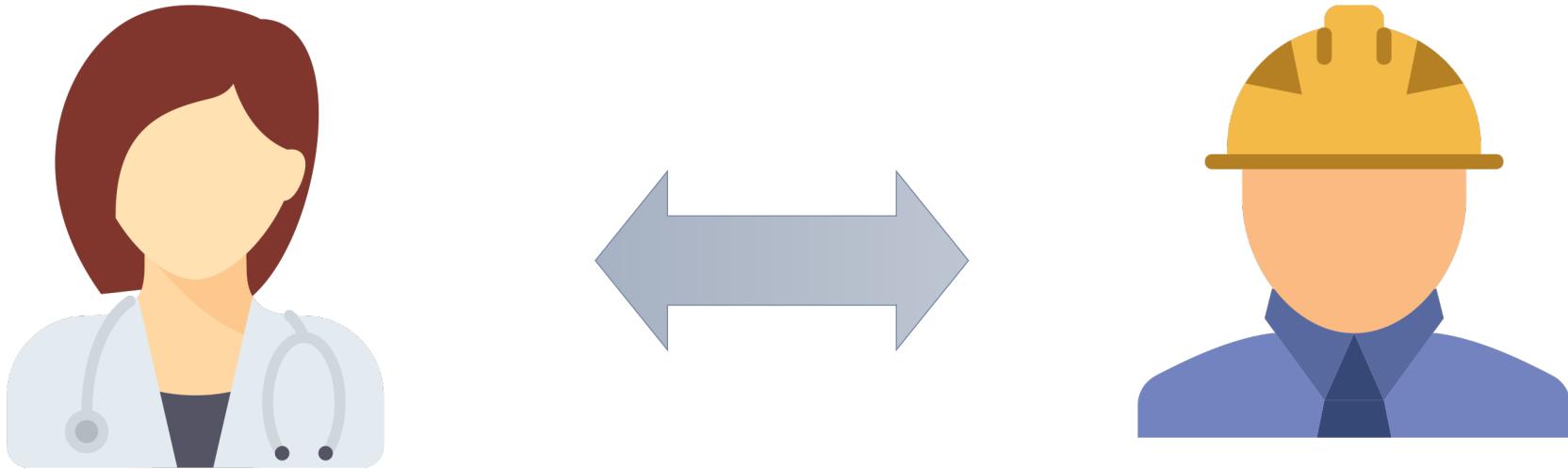
Motion and Muscle
Signals

Integrated platform to inspect, compare and analyze the multimodal motion assessment data.

Task and Design

Task and Design

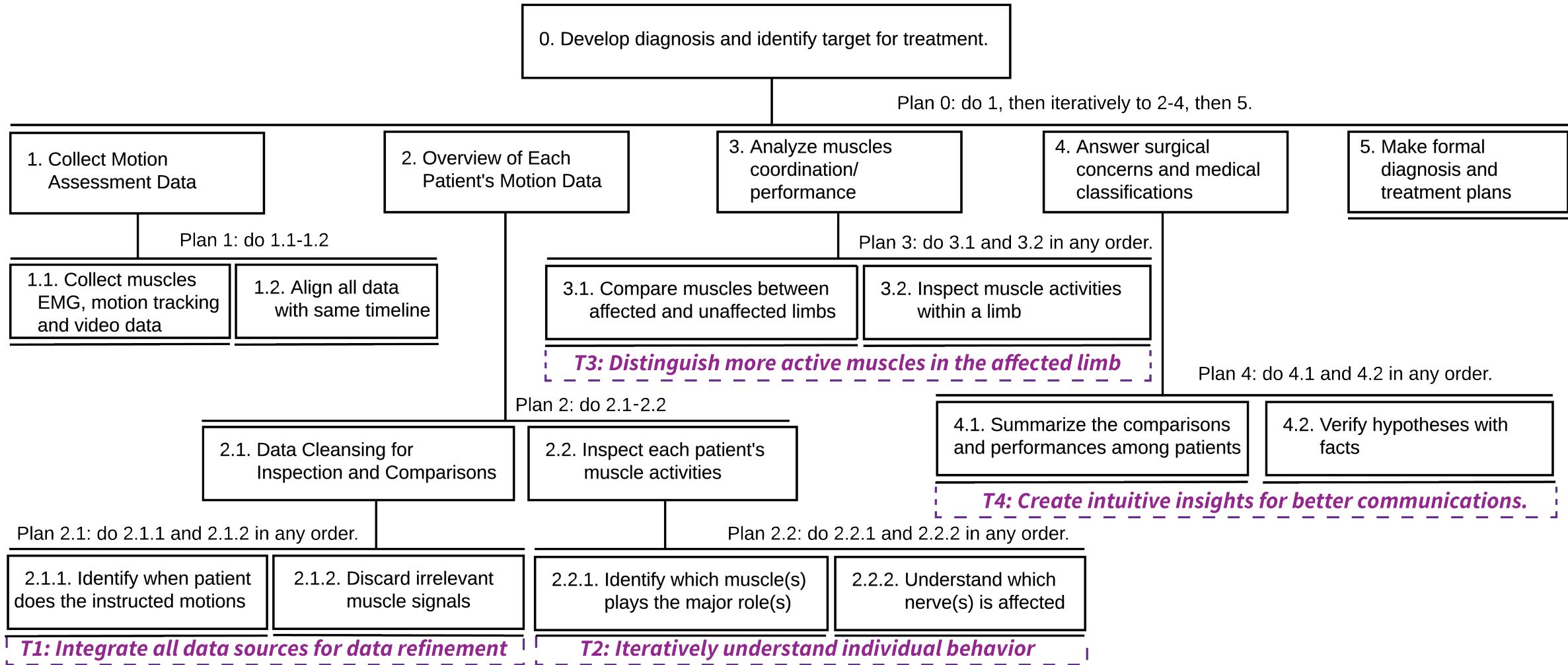
Task Abstraction



How to extract system requirements from
professional medical workflow?

Task and Design

Task Abstraction



Task and Design

Task Abstraction

Hierarchical Task Analysis (HTA):

- A hierarchical approach to describe users' performance of tasks.
- Break down specific goals to subgoals, operations, and plans.
- Recently used to bridge medical operations and system requirements in visualization design studies (Zhang et. al. TVCG 2019)

Plan 0: do 1, then iteratively to 2-4, then 5.

Plan 1: do 1.1-1.2

Plan 2: do 2.1 and 2.2 in any order.

Plan 3: do 3.1 and 3.2 in any order.

Plan 4: do 4.1 and 4.2 in any order.

Plan 2.1: do 2.1.1 and 2.1.2 in any order.

Plan 2.2: do 2.2.1 and 2.2.2 in any order.

2.1.1. Identify when patient does the instructed motions

2.1.2. Discard irrelevant muscle signals

2.2.1. Identify which muscle(s) plays the major role(s)

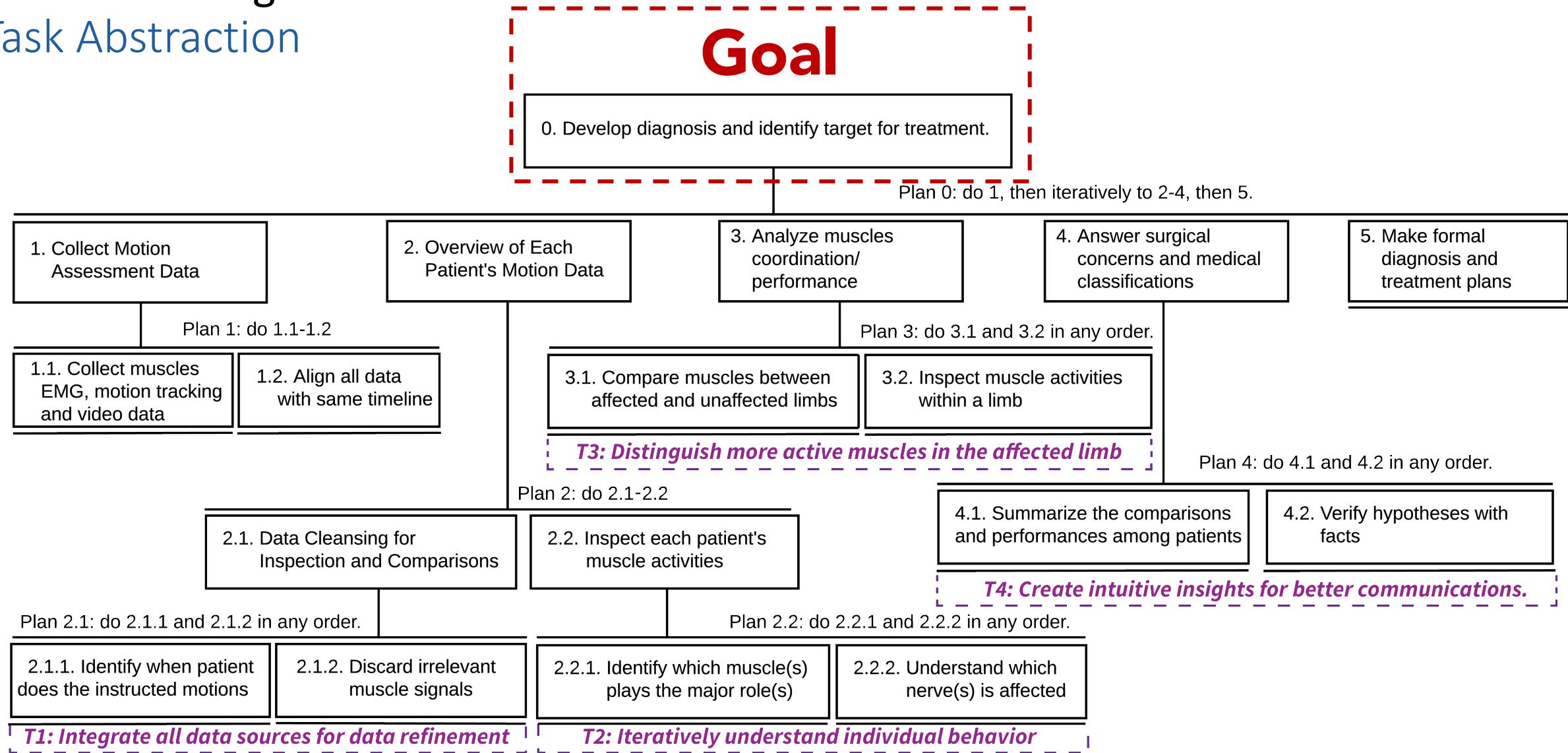
2.2.2. Understand which nerve(s) is affected

T1: Integrate all data sources for data refinement

T2: Iteratively understand individual behavior

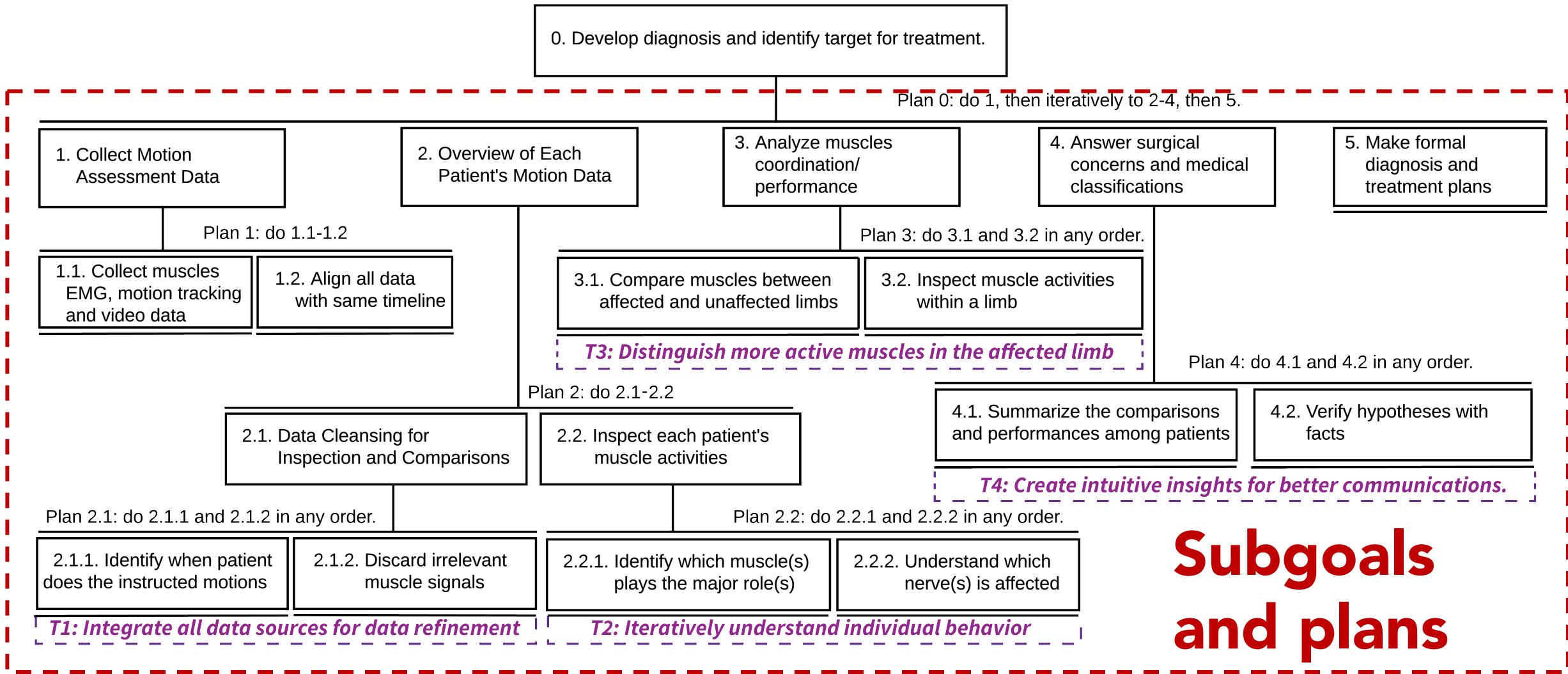
Task and Design

Task Abstraction



Task and Design

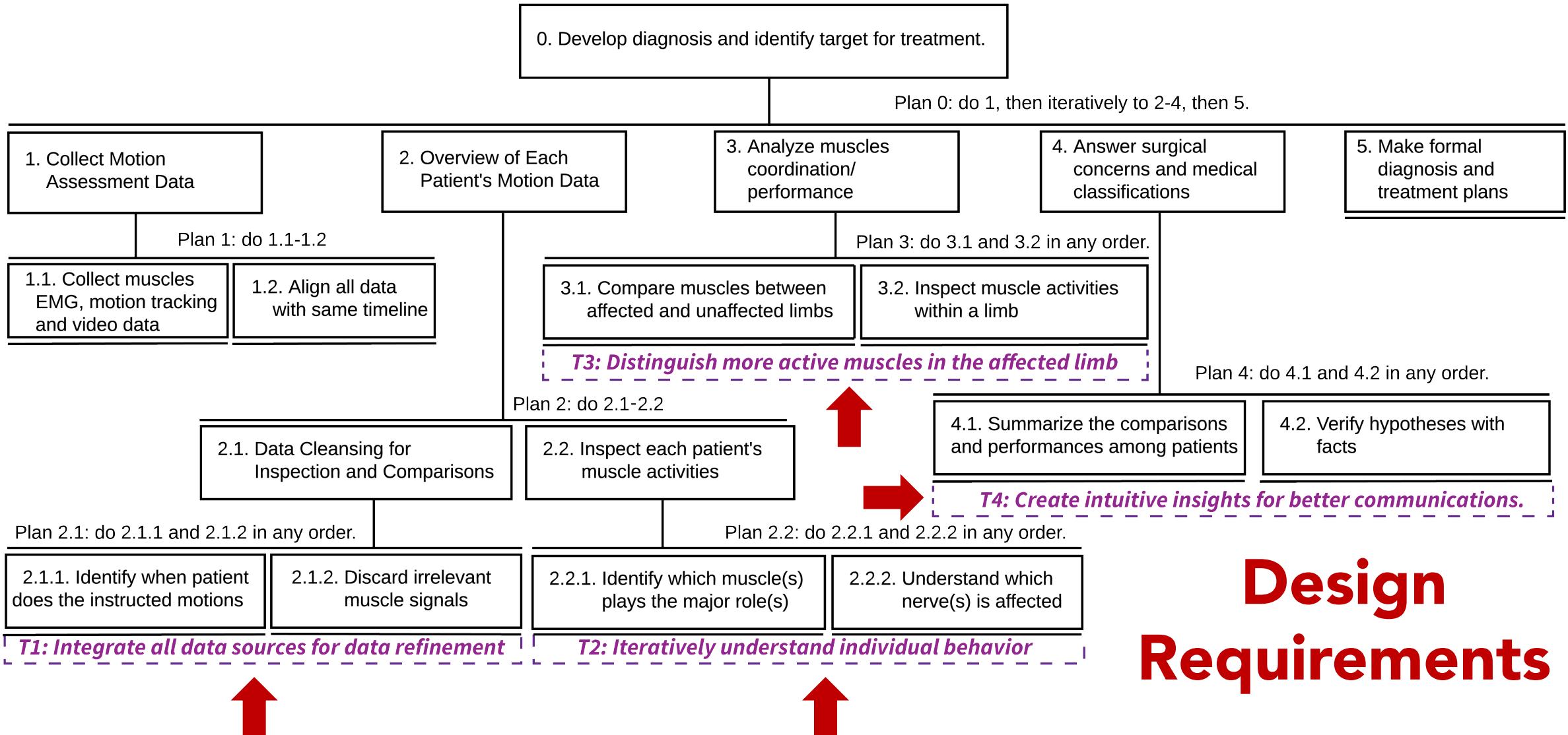
Task Abstraction



Subgoals and plans

Task and Design

Task Abstraction



Design Requirements

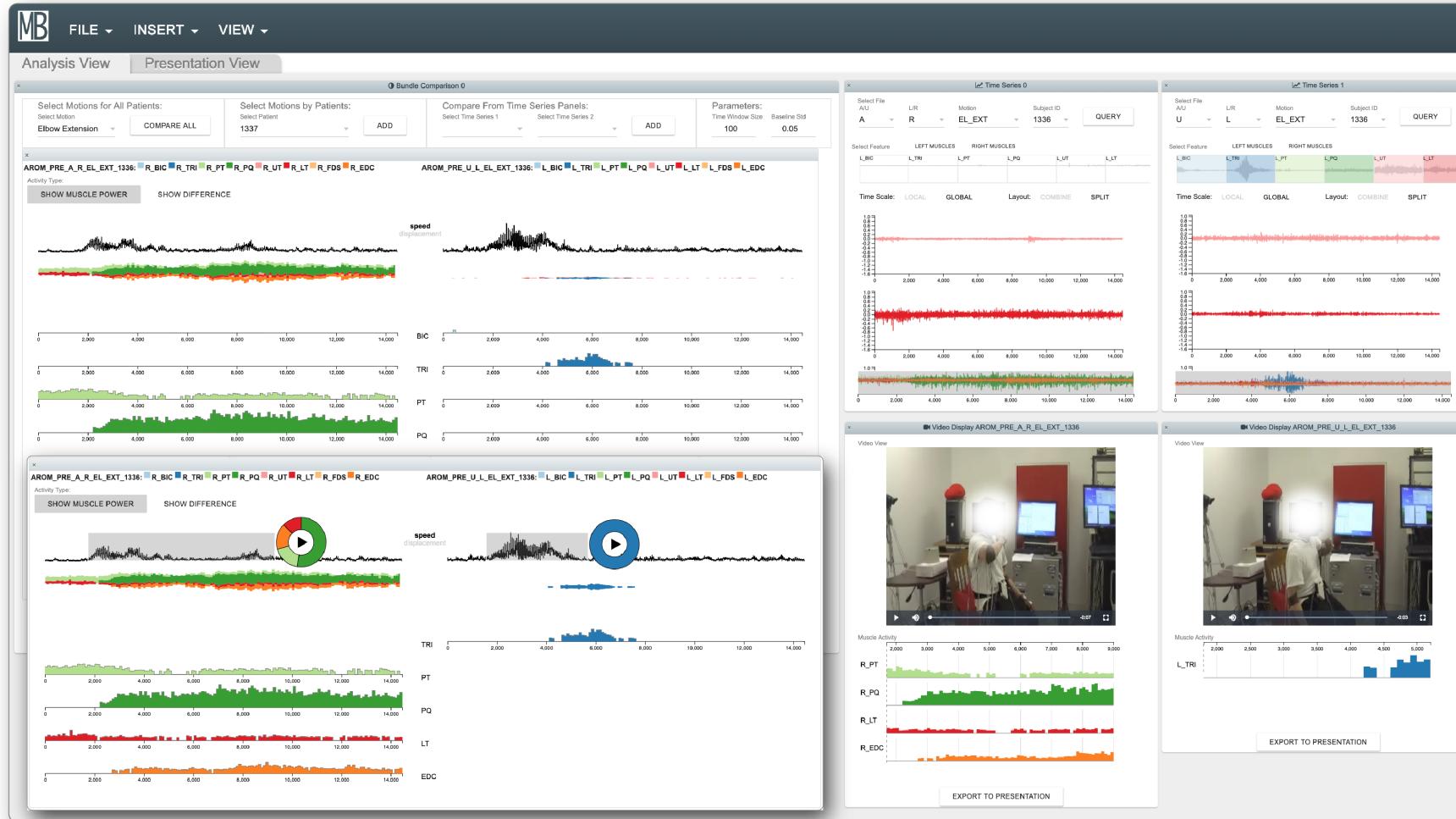
Task and Design

Task Abstraction

Design Requirements:

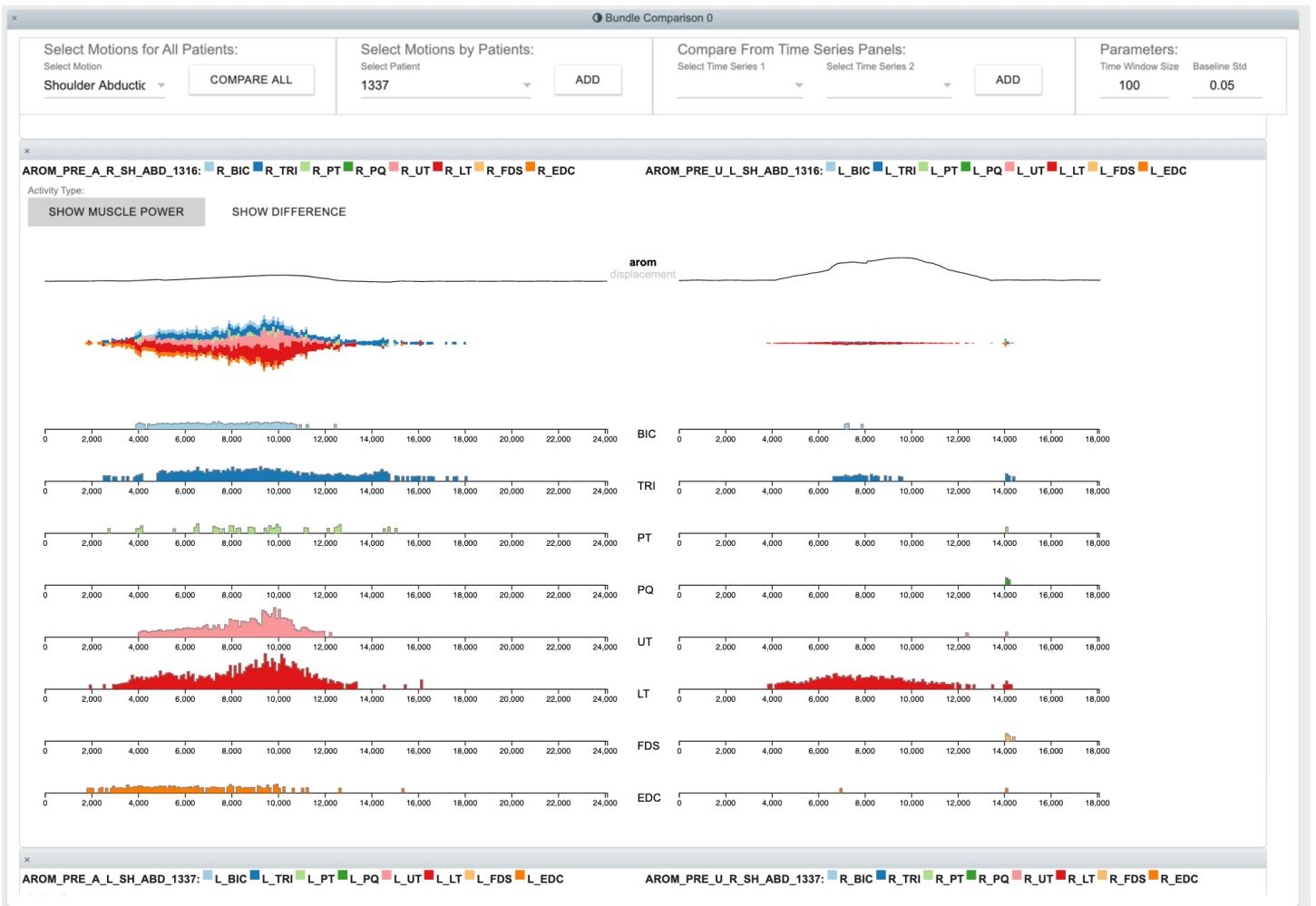
1. Align heterogeneous data sources temporally.
 - 1.1. Collection of Assessment Data
 - 1.1.1. EMG, motion tracking and video data
 - 1.1.2. Alignment of data with same timeline
 - Plan 1: do 1.1-1.2
 - 0. Develop diagnosis and identify target for treatment.
 - 0.1. Overview of Patient Motion Data
 - 0.2. Analyze muscles involved in motion performance
 - Plan 0: do 1, then iteratively to 2-4, then 5.
 - 3. Answer surgical concerns and medical classifications
 - 5. Make formal diagnosis and treatment plans
2. Display and analyze performance in one view for each patient.
 - 1.1.1.1. Plan 2: do 2.1-2.2
 - 2.1.1.1. Distinguish more active muscles in the affected limb
 - 2.1.1.2. Within a limb, affected and unaffected limbs
 - Plan 3: do 3.1 and 3.2 in any order.
 - 3.1. Inspect each patient's muscle activities
 - 3.2. Summarize the comparisons and performances among patients
 - Plan 4: do 4.1 and 4.2 in any order.
 - 4.1. Verify hypotheses with facts
 - 4.2. Create intuitive insights for better communications.
3. Enable efficient comparative analysis.
 - 2.1. Data Cleansing for Inspection and Comparisons
 - 2.1.1. Identify when patient does the instructed motions
 - 2.1.2. Discard irrelevant muscle signals
 - 2.2. Inspect each patient's muscle activities
 - 2.2.1. Identify which muscle(s) plays the major role(s)
 - 2.2.2. Understand which nerve(s) is affected
4. Export the clinical analysis for presentation.
 - 2.1.1.1. T1: Integrate all data sources for data refinement
 - 2.1.2.1. T2: Iteratively understand individual behavior
 - 2.2.1.1. T3: Distinguish more active muscles in the affected limb
 - 2.2.2.1. T4: Create intuitive insights for better communications.

Task and Design System Design



Task and Design System Design

The system first loads the motion result for each patient in each window.



Task and Design

System Design

Motion results of the affected limb are placed on the left-hand side, while results of the unaffected limb are on the right-hand side.

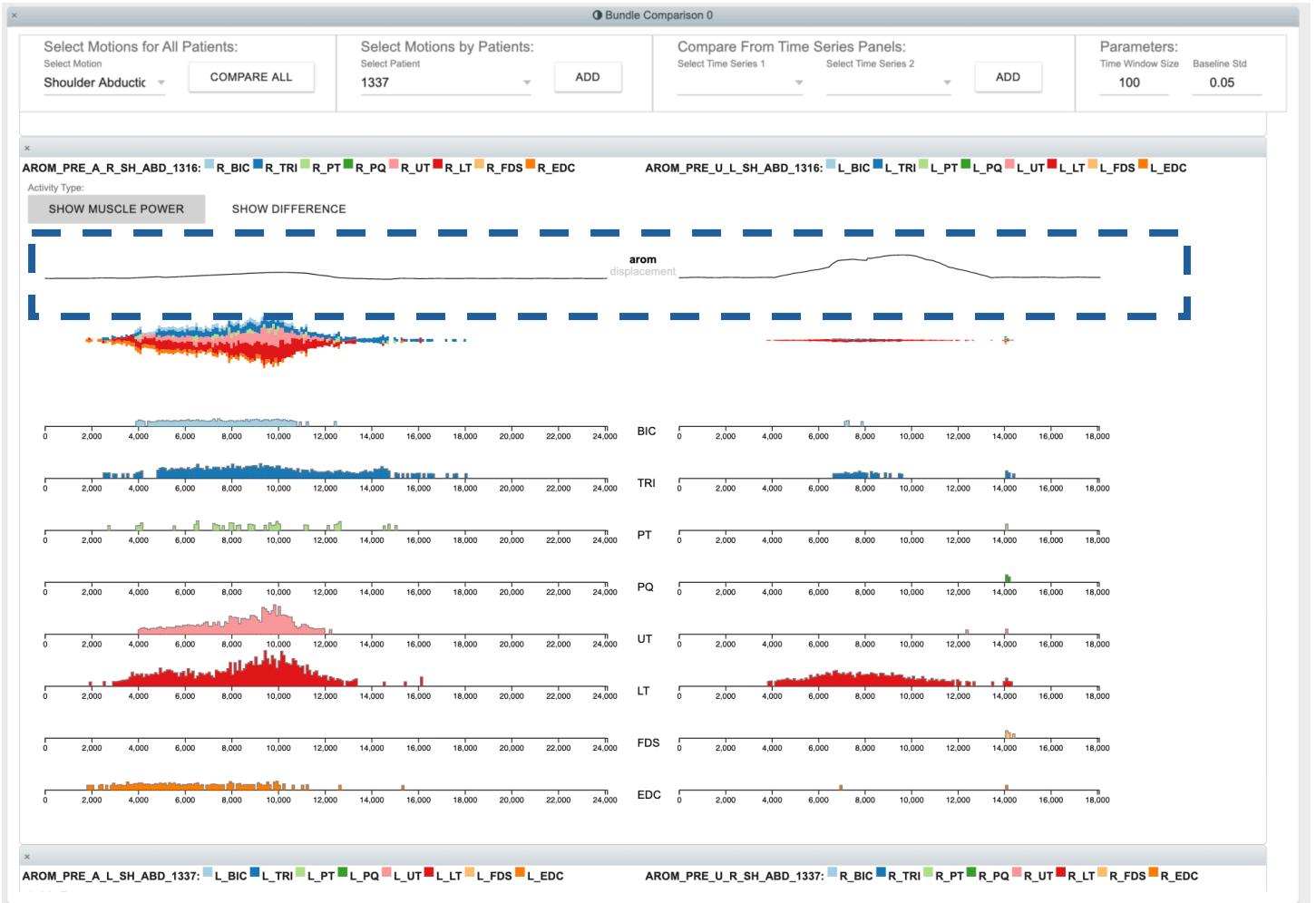
Affected Limb

Unaffected Limb



Task and Design System Design

Line chart shows the motion results (e.g. the displacement/ rotation of the limb)



Task and Design

System Design

Bar charts show the muscle activations.

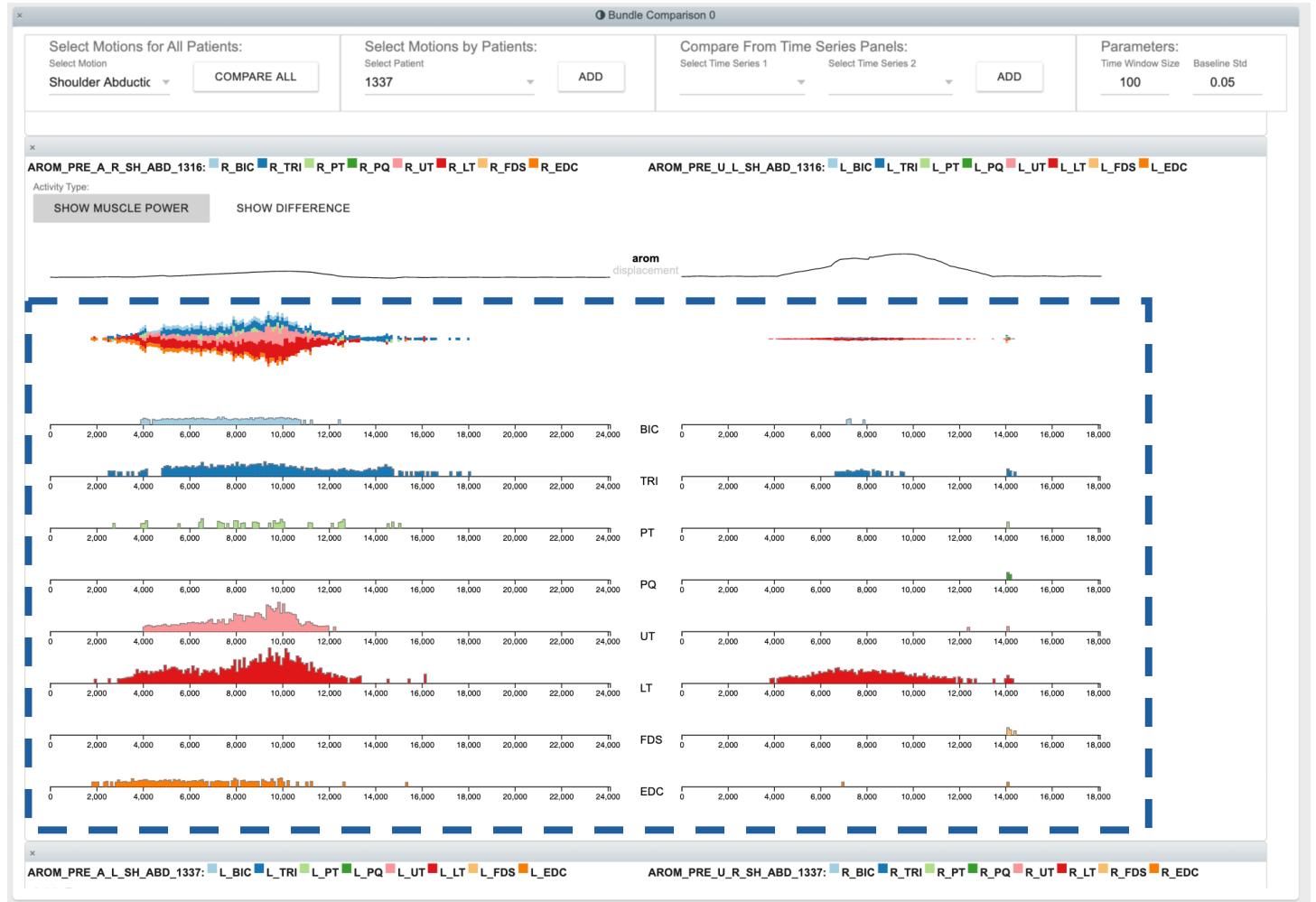
Same muscles from both limbs are encoded with the same color and vertical position.

  BIC, TRI (Muscles from the upper arm)

  PT, PQ (Muscles from the forearm)

  UT, LT (Muscles from the back)

  FDS, EDC (Muscles from the fingers)



Task and Design System Design

Although placing patients in each view allows physicians to get a clear inspection of patients' data, comparing muscles one by one is a tedious task.

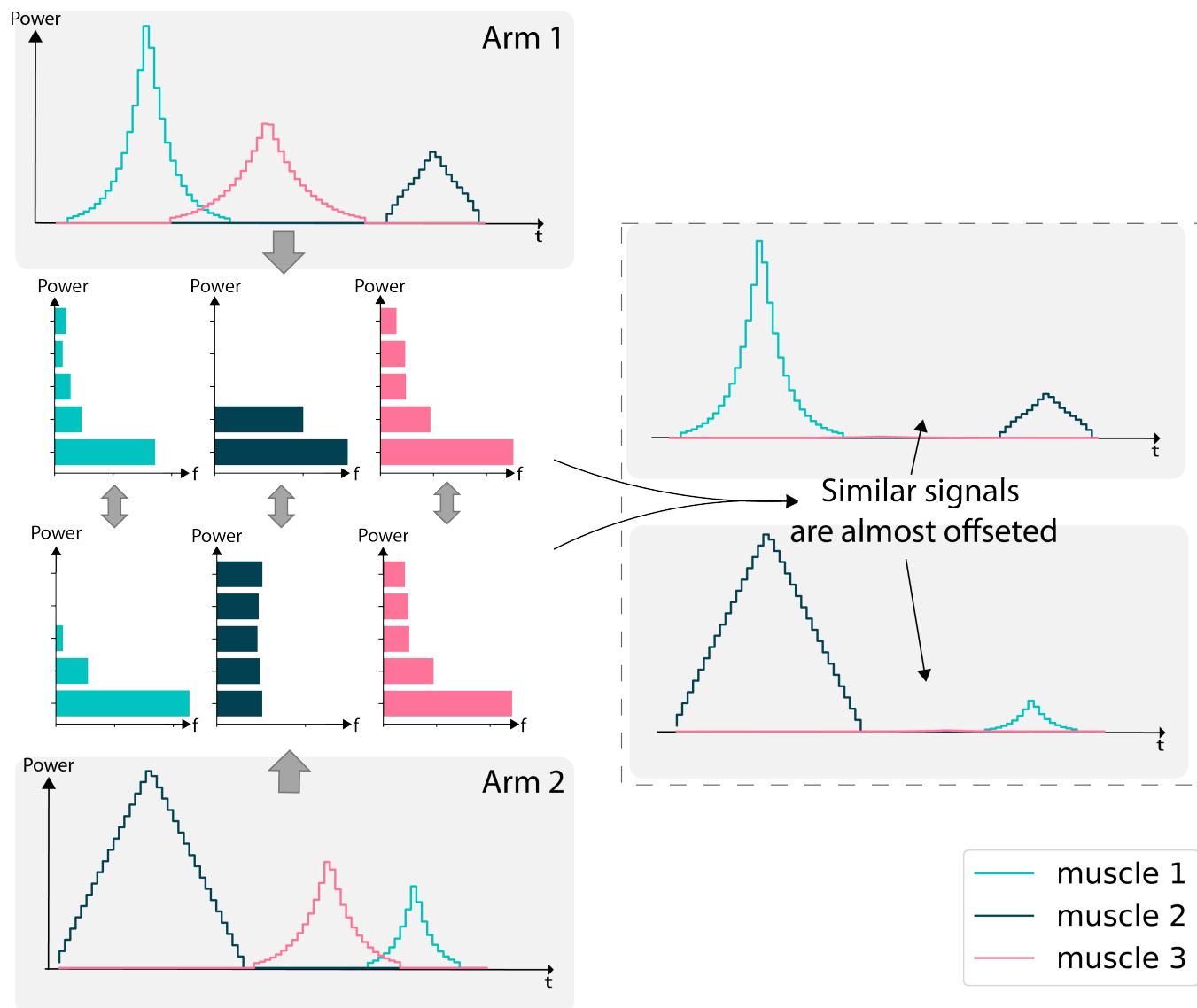


Task and Design

System Design

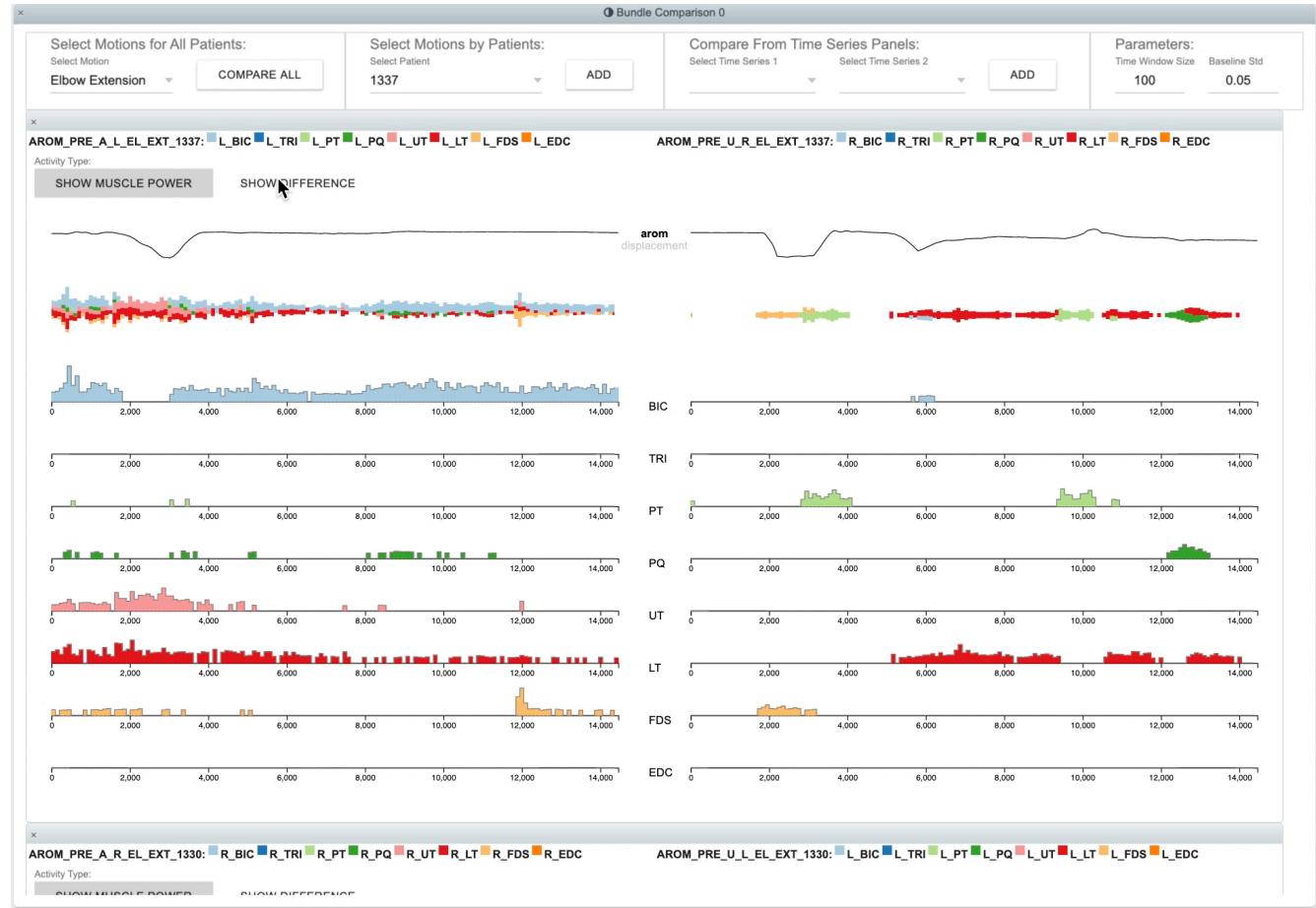
Remove similar muscle activities:

1. Transform the signals of each muscle into a histogram.
2. Compute the KL-divergence of the histograms between the limbs.
3. The lower the values of KL-divergence, the more similar the muscle activities are.



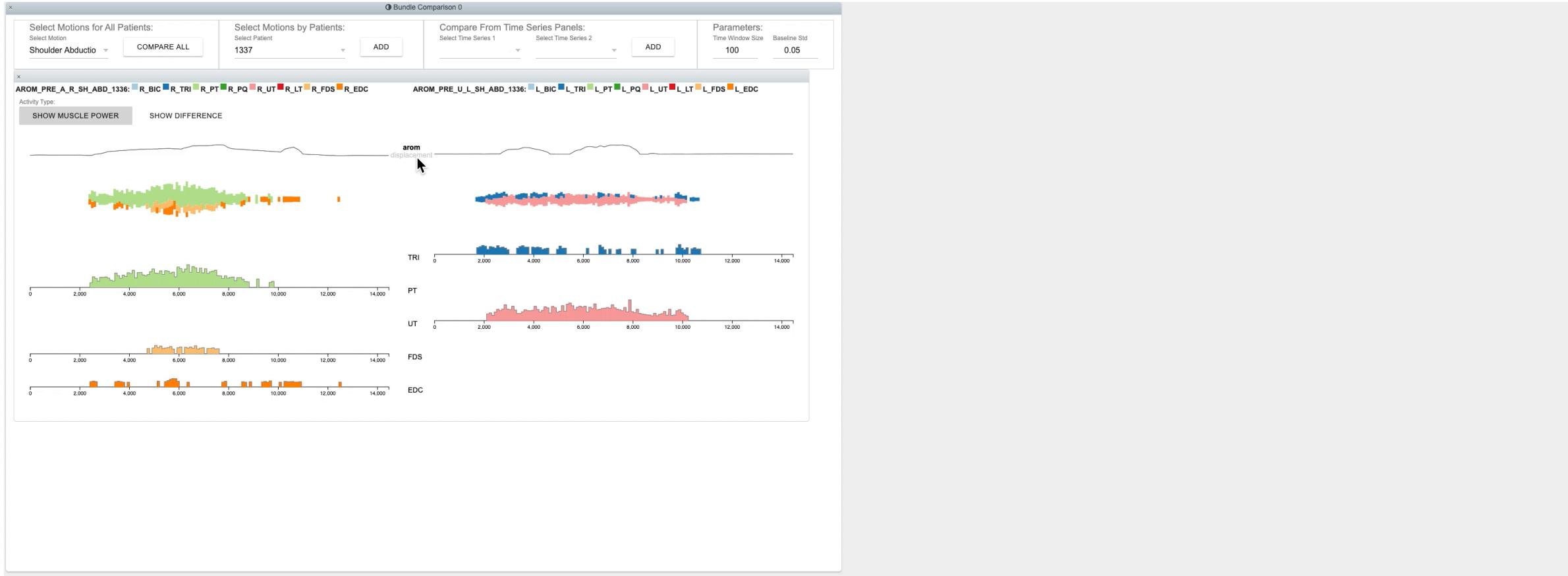
Task and Design System Design

The technique allows analysis through filtering, speeding up the interactions per patient.



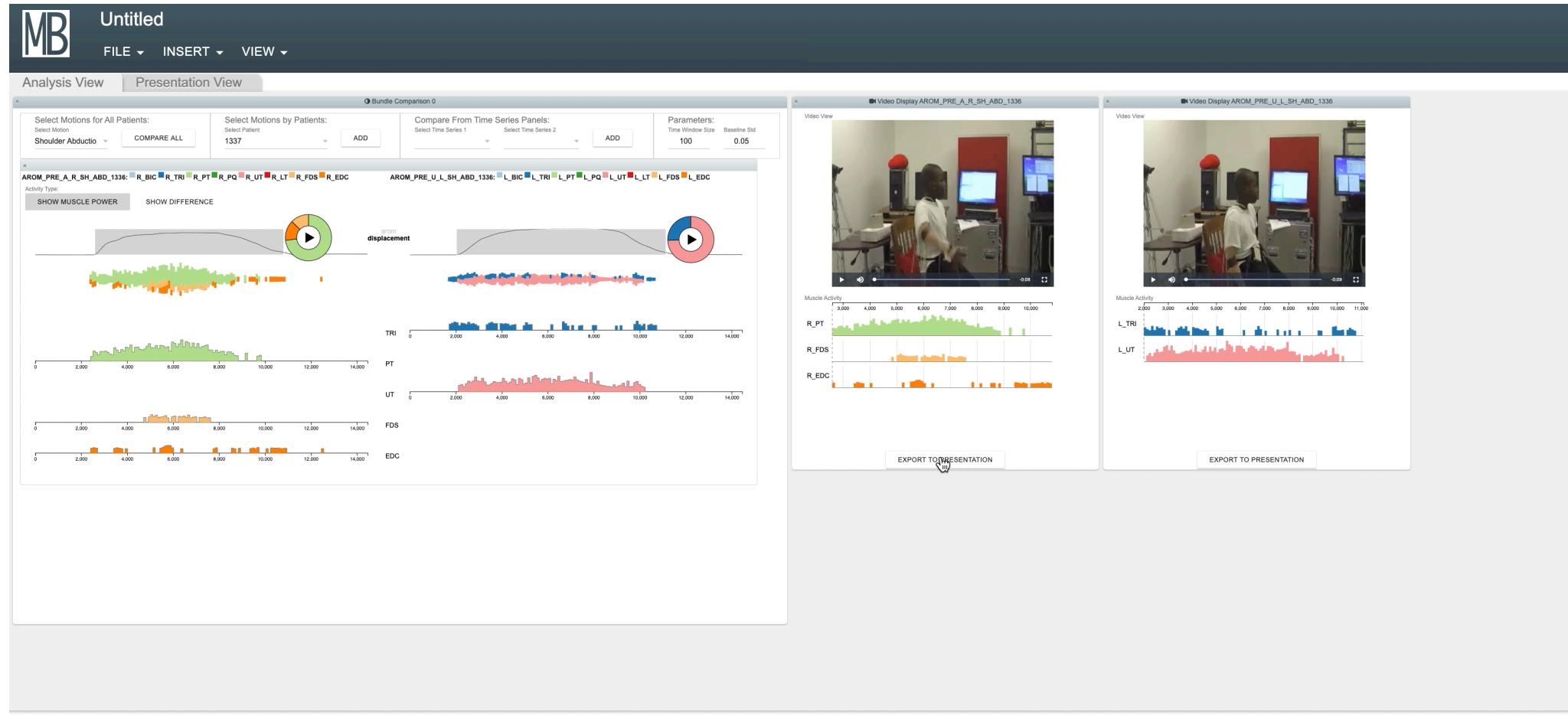
Task and Design

System Design



Extract video cutscenes

Task and Design System Design

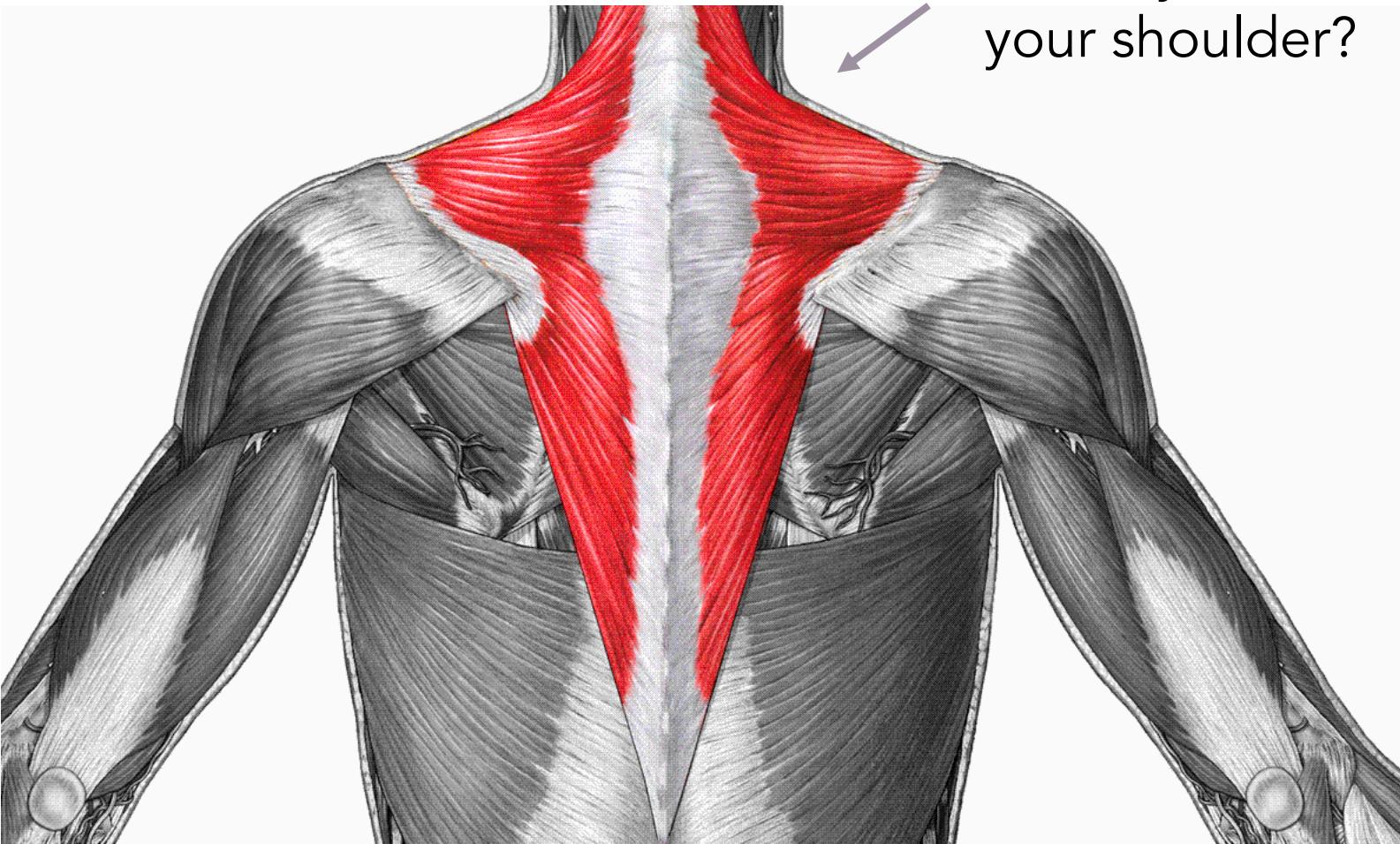


Presentation View

Case Study

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion



Do they move
your shoulder?

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion



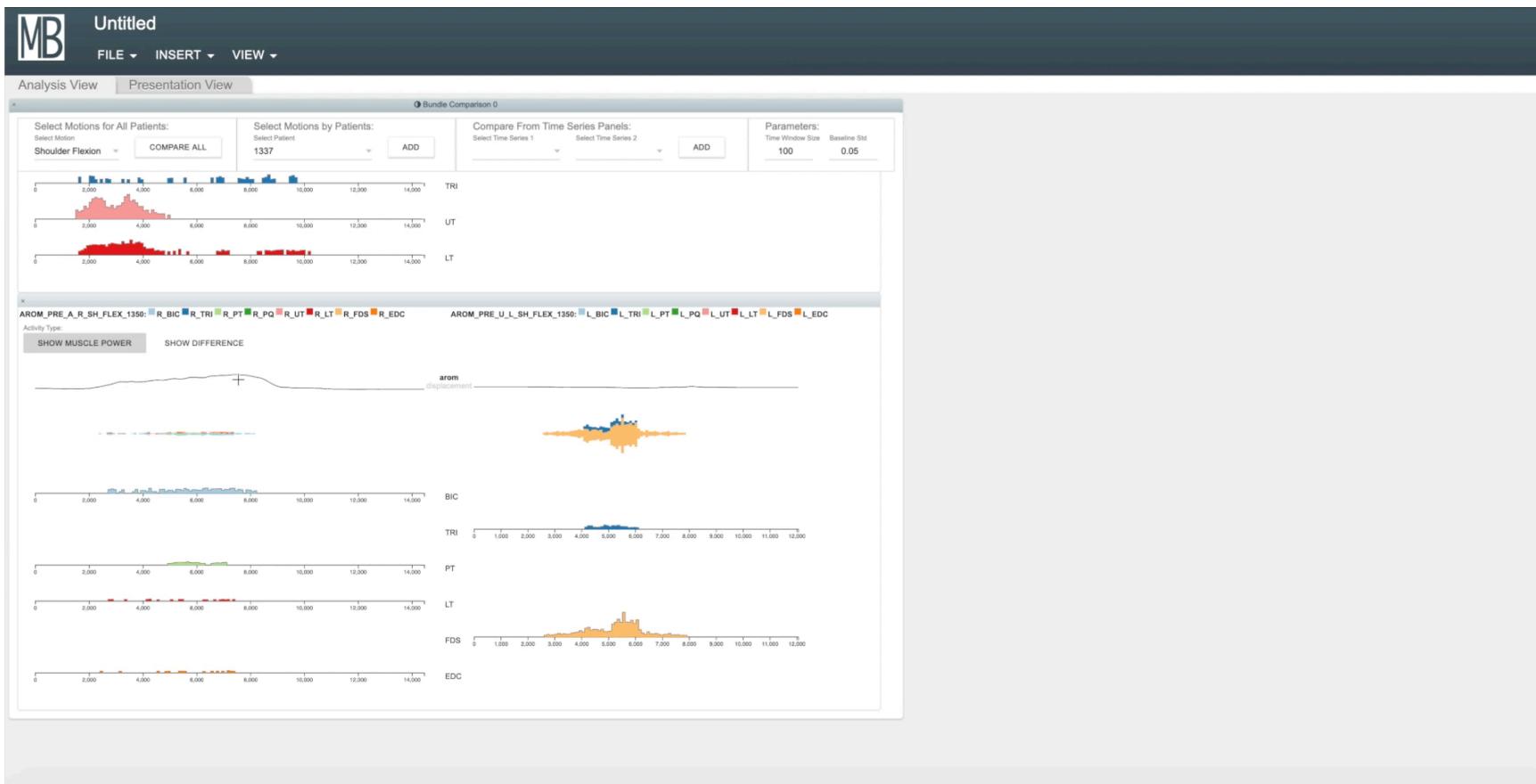
Upper Trapezius Muscles



Lower Trapezius Muscles

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion



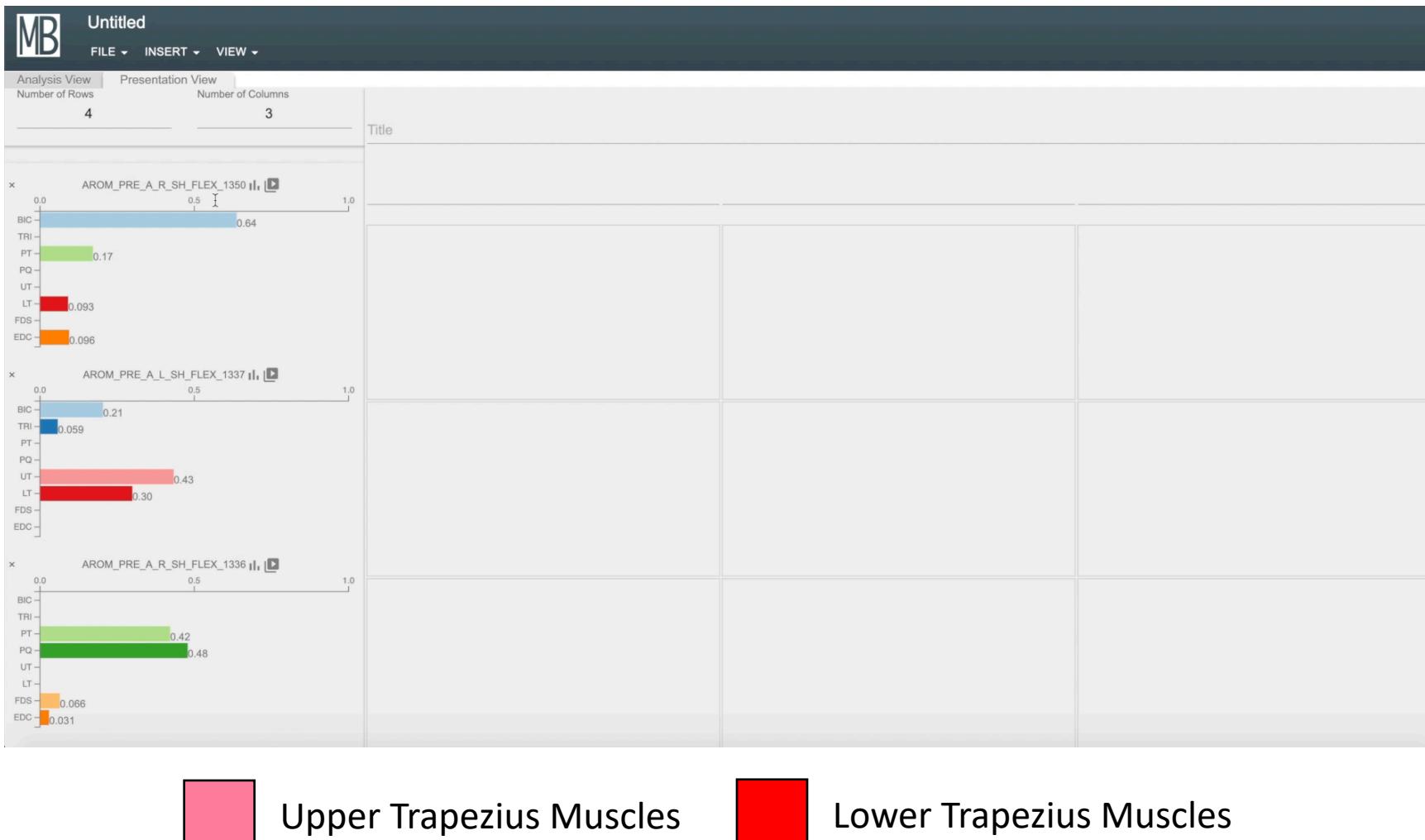
Upper Trapezius Muscles



Lower Trapezius Muscles

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion



Upper Trapezius Muscles

Lower Trapezius Muscles

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion

3 groups of patients



Upper Trapezius Muscles

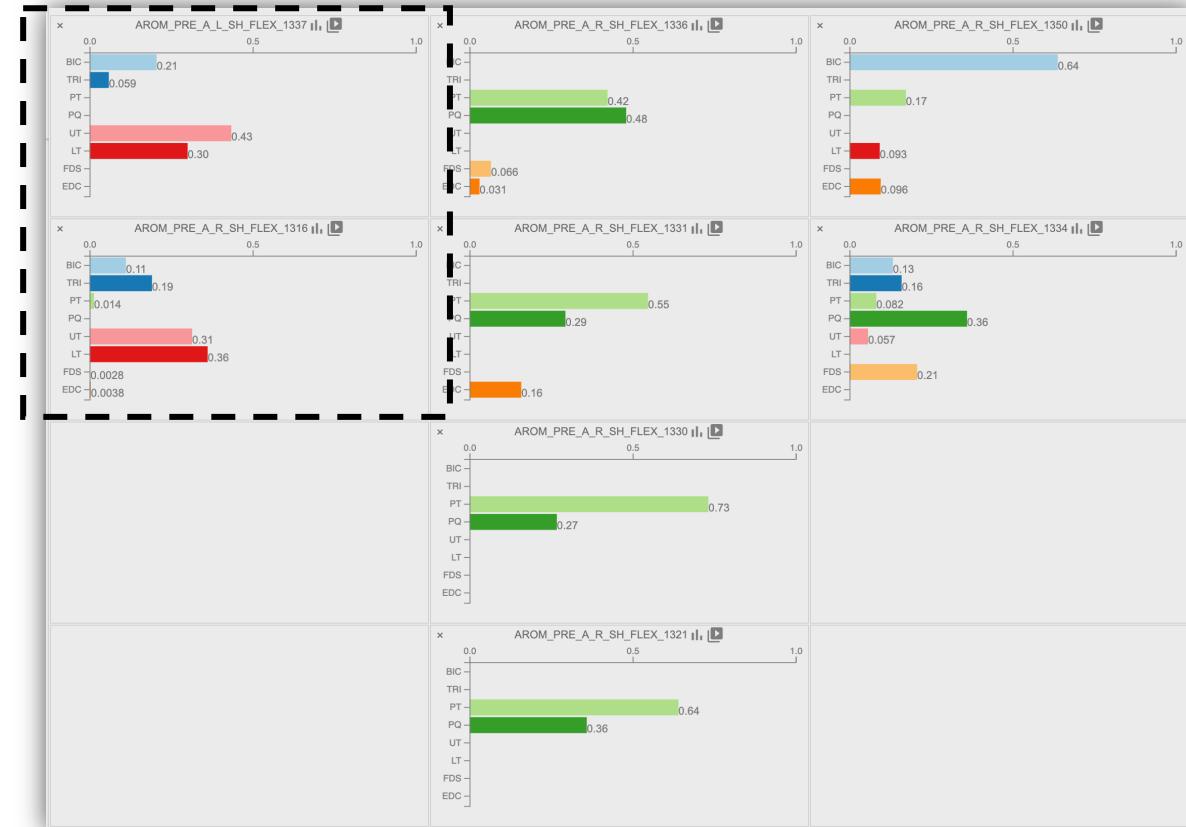
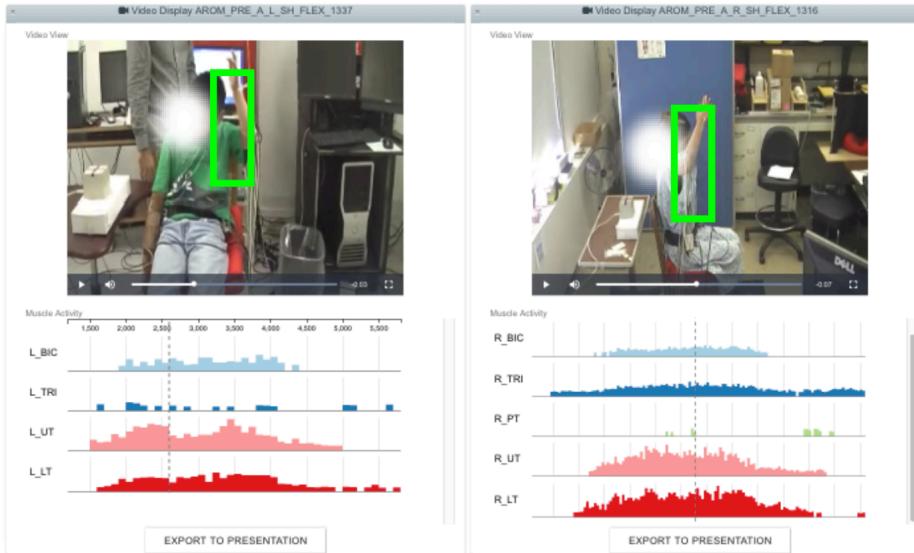


Lower Trapezius Muscles

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion

Patients overfiring their muscles



Upper Trapezius Muscles

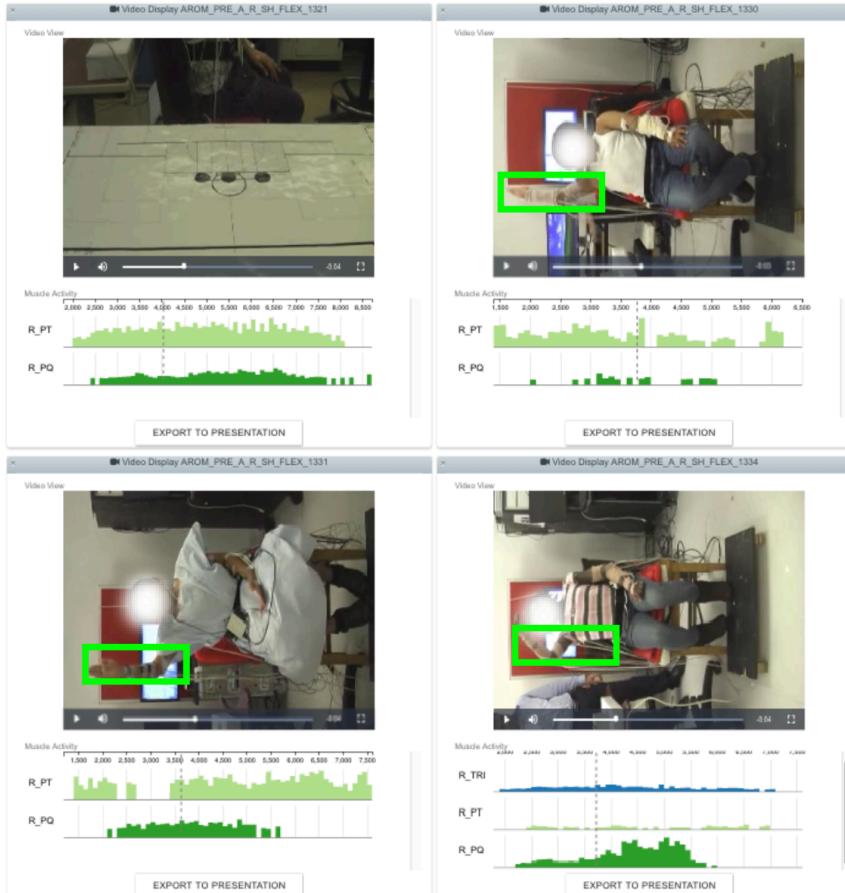


Lower Trapezius Muscles

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion

Patients not using trapezius muscles



Upper Trapezius Muscles



Lower Trapezius Muscles

Case Study

Usefulness of Trapezius Muscles on Shoulder Motion

Patients using trapezius muscles



Upper Trapezius Muscles



Lower Trapezius Muscles

Conclusion

Conclusion

Takeaway and Future Work

1. Task analysis on medical domain requires extra effort
2. Reducing cycle time on repeated interactions is useful
3. More statistical analysis is required to be able to submit to medical journal (ongoing)

Thank you



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