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Data Analytics Framework for A Game-based Rehabilitation System

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Outline

- Motivation
- Introduction
- Data Analysis Framework
- Experiments
- Conclusion

Motivation

- Stroke happens when blood flow to an area of the brain stops.
- Around 4 million stroke patients in the US.
- It costs the US more than $34 billion annually.

Motivation

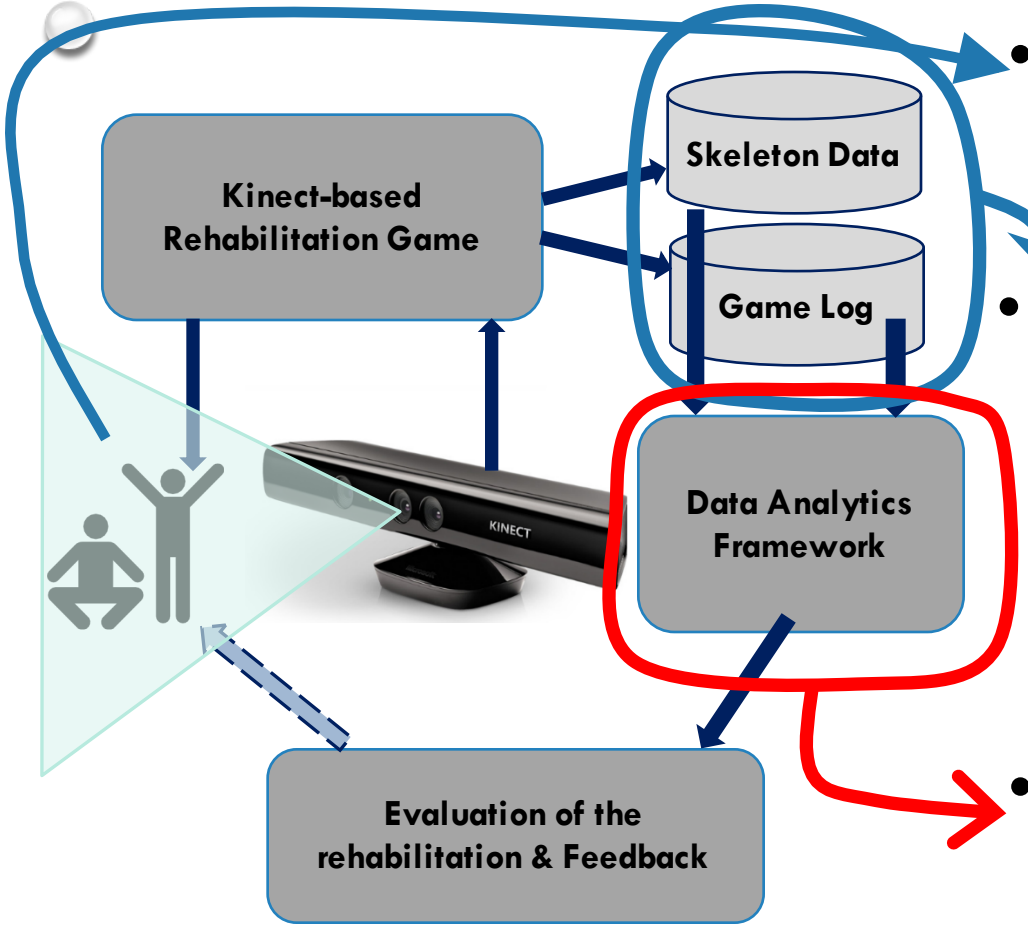
Motivation

- Getting physical therapy is difficult.
- Fewer than 1% receive it (in the US):
  - Too costly
  - Travelling difficulties for stroke patients
  - Not enough providers

Motivation

See full video at https://youtu.be/G5MyBNvNEfg

Introduction

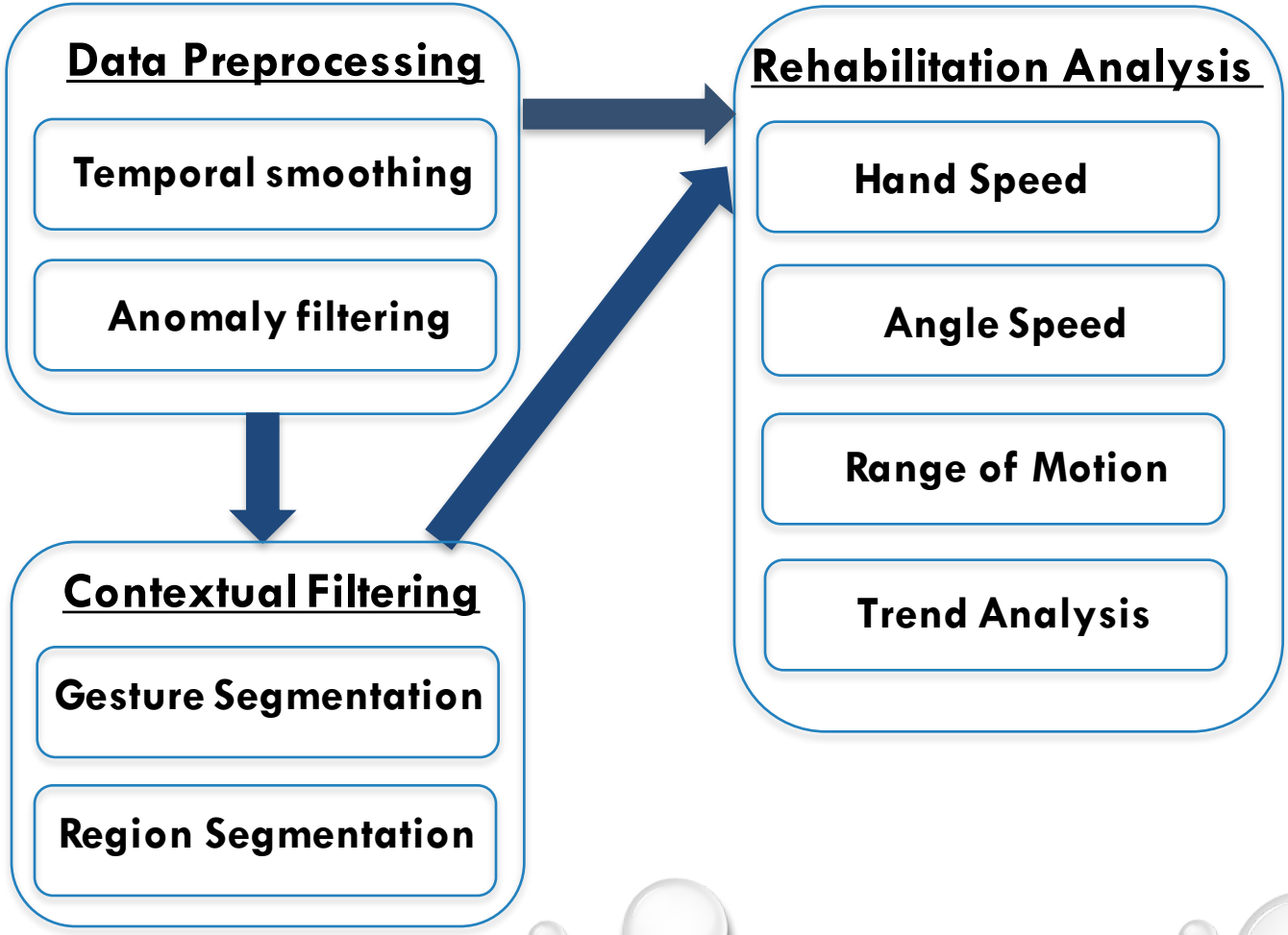


- Patients play the game in front of Kinect.
- Kinect collects *skeleton data*.
  Software recognizes gesture (*game log*).
- Data analytics for performance evaluation.

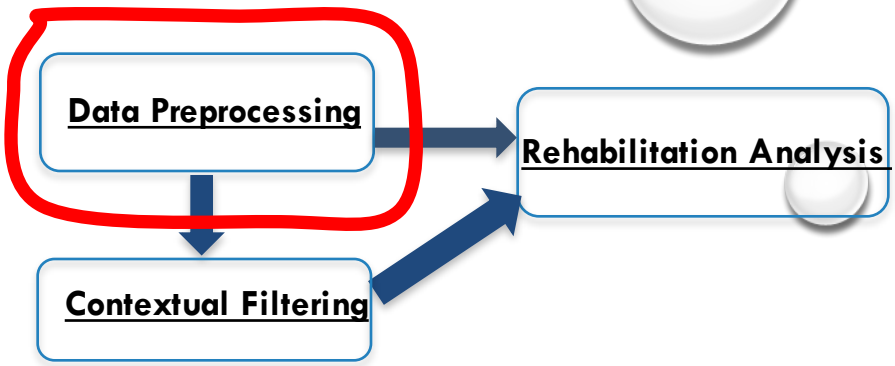
Introduction

- In this work, we
  - Propose a data analytics framework to evaluate the efficacy of the rehabilitation.
  - Show some preliminary results based on some participants we recruited.
  - Show our evaluation based on game data is consistent with a standard test in the lab.

Data Analytics framework



Data Preprocessing

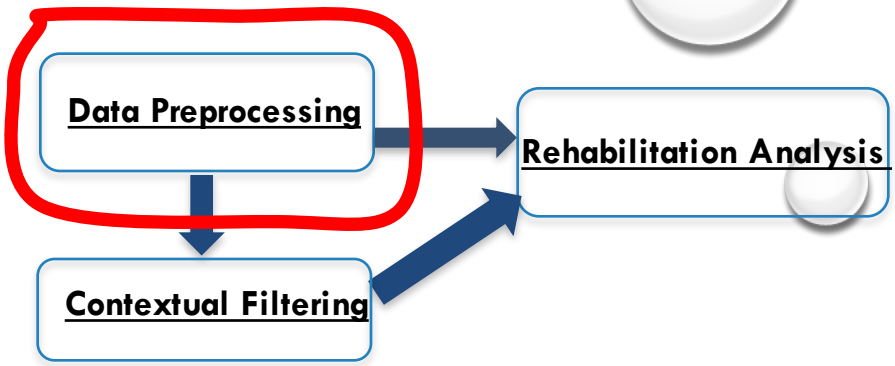


1. Temporal smoothing:

- *Problem*: limited sensor spatial resolution, but 30 snapshots each sec. Movement might be due to "jitter" and sensor limitations.

- *Solution*: set a sliding time window T (200 ms), and average snapshots.

Data Preprocessing

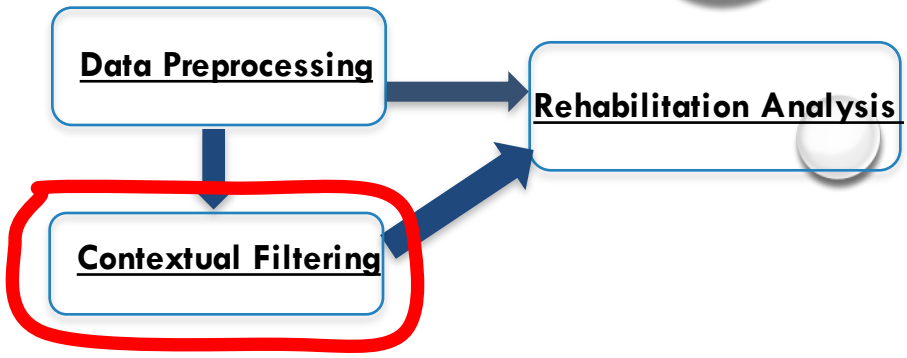


2. Anomaly filtering:

- *Problem*: there are some erroneous snapshots.

- *Solution*: Inside a time window, remove snapshot if the distance of it to the averaged snapshot > $\mu+3\sigma$.

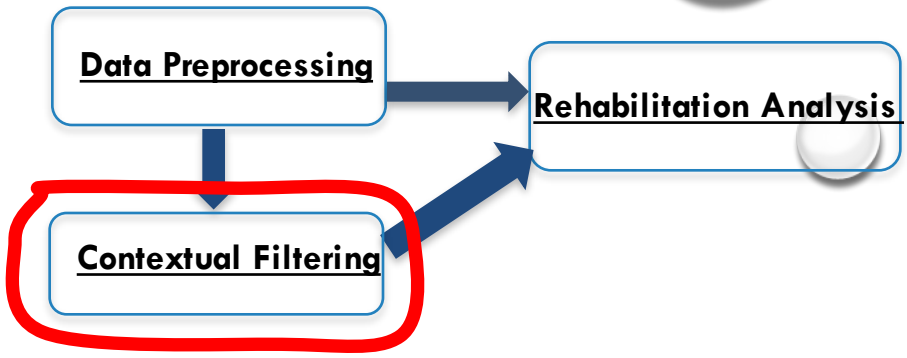
Contextual Filtering



- **Gesture Segmentation**:
- *Reason*: there are different gestures. Analyze patients' movement during each *gesture period* (dynamically).

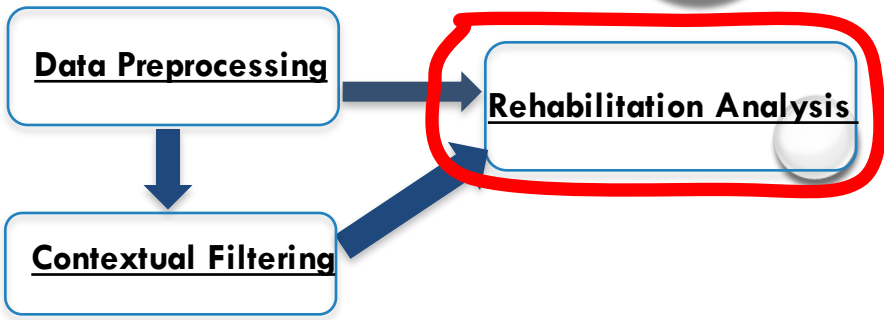
- *Solution*: concatenate continuous snapshots of the same gesture with temporal gaps smaller than 2,000 ms (using *game log*).

Contextual Filtering



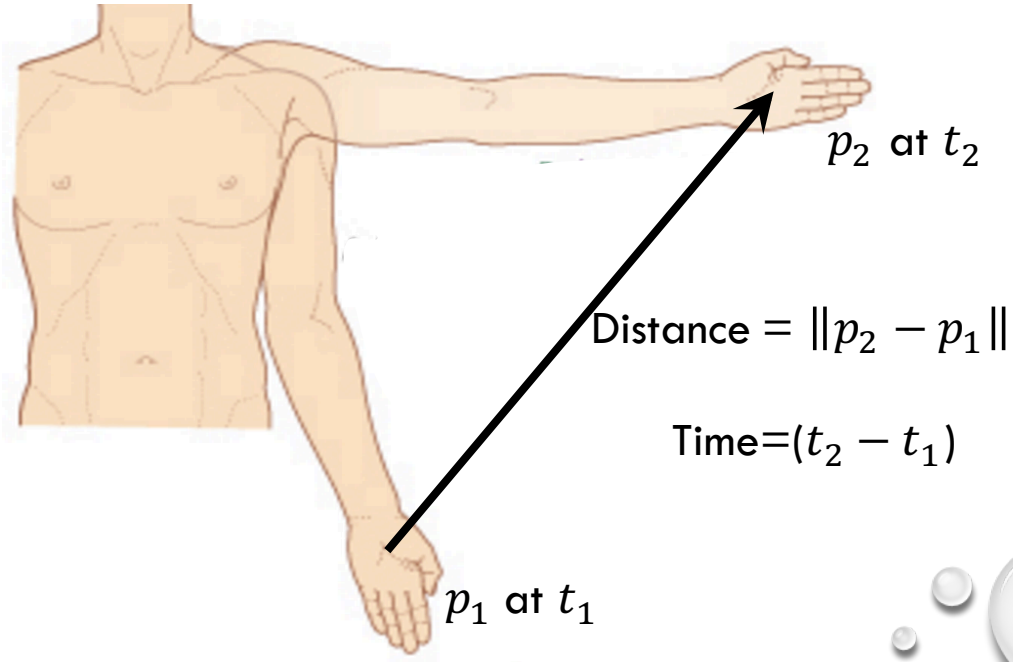
- **Region Segmentation**:
- *Reason*: the game contains several different regions with different difficulties and intensities.
  - ✓Self-paced movement: e.g., Rowing.
  - ✓Fast-paced movement: e.g., Rapids.
- *Solution*: refer to the game log, synchronize the timestamp and segment out skeleton data.

Rehabilitation analysis

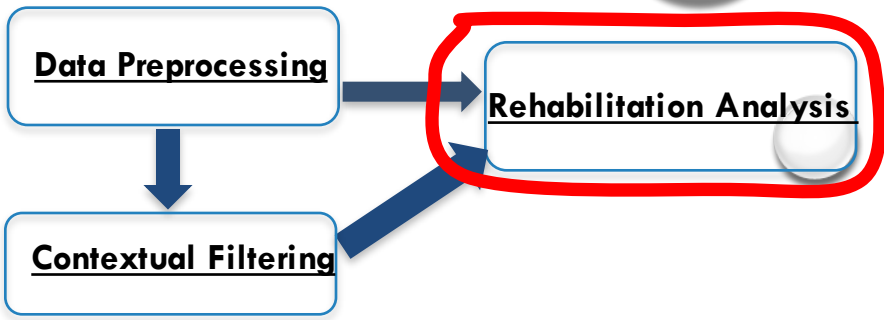


- **Hand speed**: movement speed of hand.

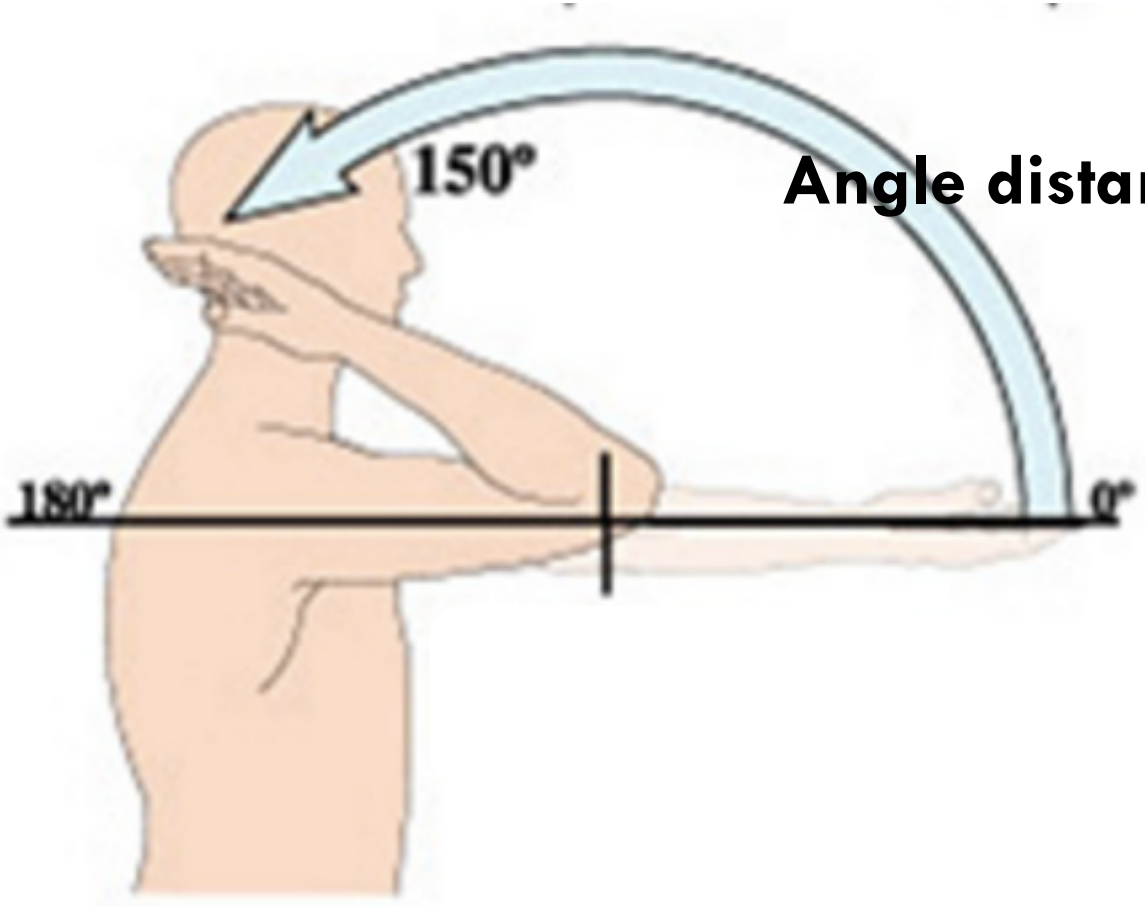
$$v_d = \frac{\sum_{i=2}^{n} \|p_i - p_{i-1}\|}{\sum_{i=2}^{n} (t_i - t_{i-1})}$$



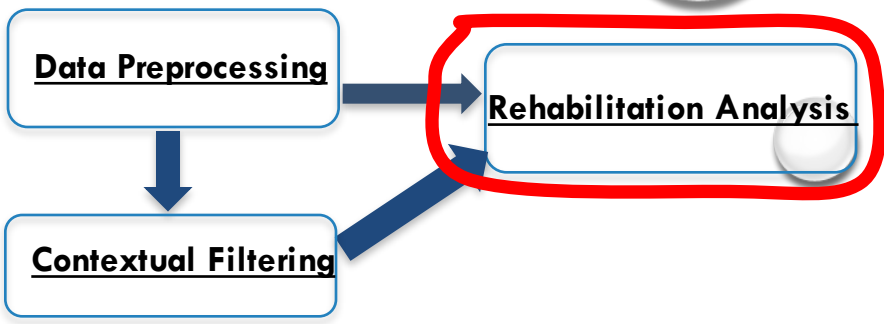
Rehabilitation analysis



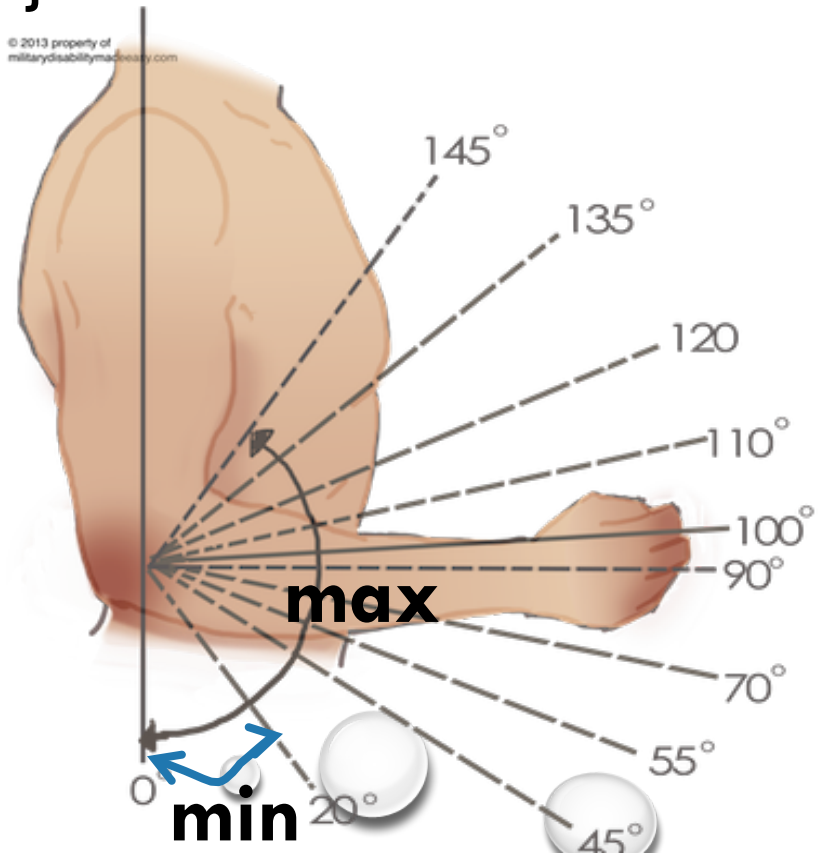
- **Angle speed**: similar to movement speed, but on angle.



Rehabilitation analysis



- **Range of Motion**: difference between min and max angles of a body joint. It measures the active range.



Experiment Analysis

- 8 participants were recruited (at least 3 months post-stroke)

Participant ID	Affected Side	Days	Total Mins	Avg mins/day
P1	Left	21	678.6	32.3
P2	Right	14	803.2	57.4
P3	Left	19	656	34.5
P4	Right	21	978.5	46.6
P5	Right	20	2185.5	109.3
P6	Right	21	2084.3	99.3
P7	Right	20	1351.4	67.6
P8	Right	13	881.6	67.8

Experiment Analysis

- Pre/post comparison: *before* and *after* the participants used the rehab system, they conduct Wolf Motor Function Test (WMFT).

- The test measures the time to perform 15 standardized motor tasks.
- Examples: lifting pencil and placing the hand on top of a box.
- Calculate the rate based on the time.

Experiment Analysis: three parts

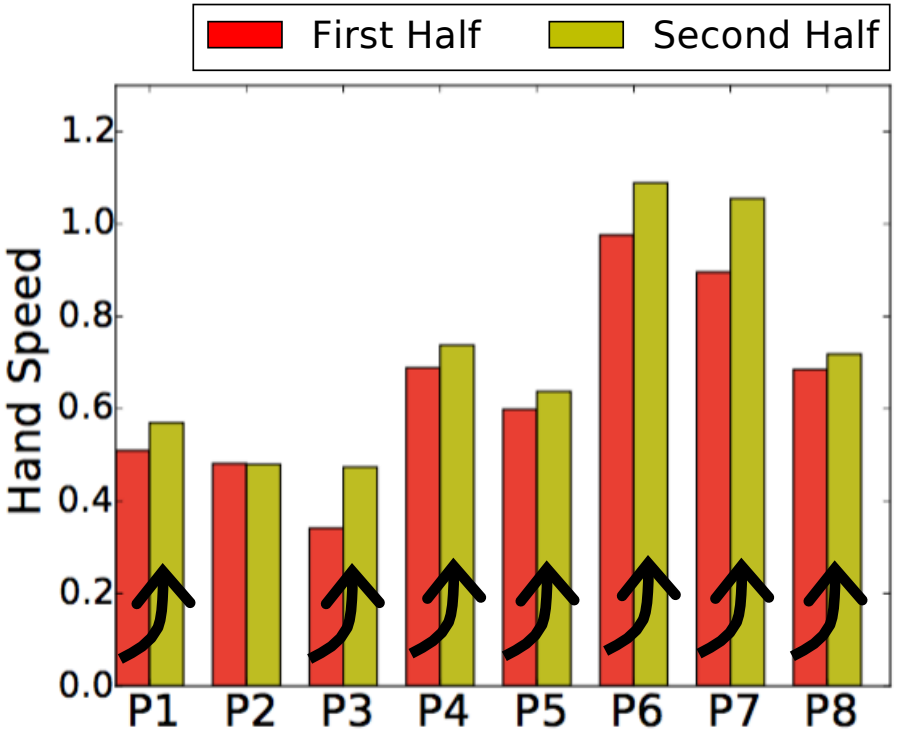
- Two-half Comparison
- Region Segment
- Trend Analysis

Experiment Analysis

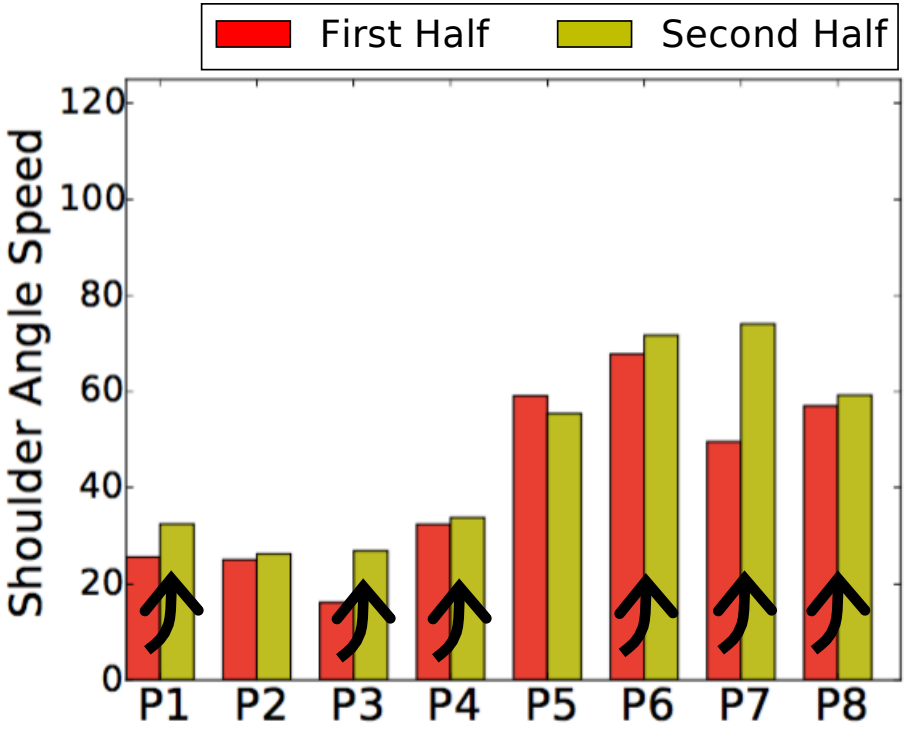
- Two-half comparison approach:
  - Divided the whole rehabilitation period into two halves.
  - Calculate the kinematic variables in these two divisions respectively (hand speed, angle speed, etc.).
  - Compare the averaged values of two halves.
  - Conduct t-test to see the significance of difference.
- Compare with WMFT result.

Experiment Analysis

- Observation 1: Improvements over the two halves.



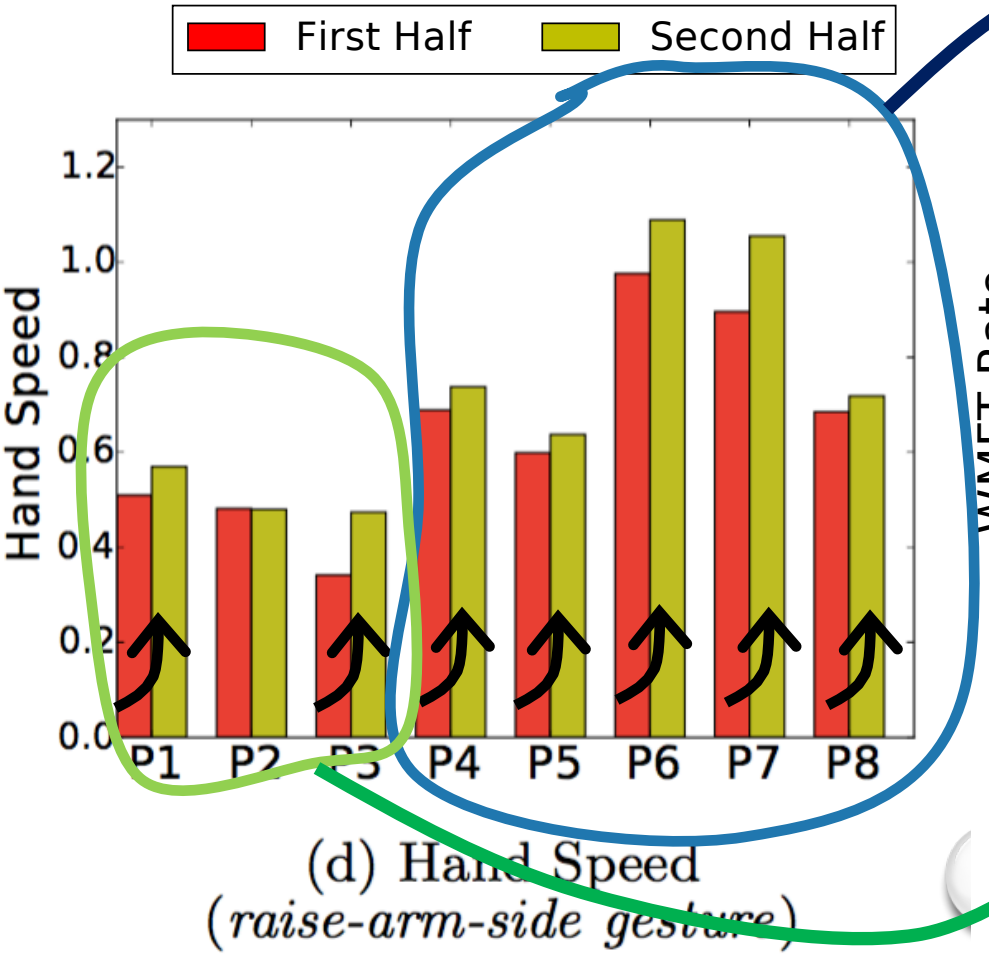
(d) Hand Speed
(*raise-arm-side gesture*)



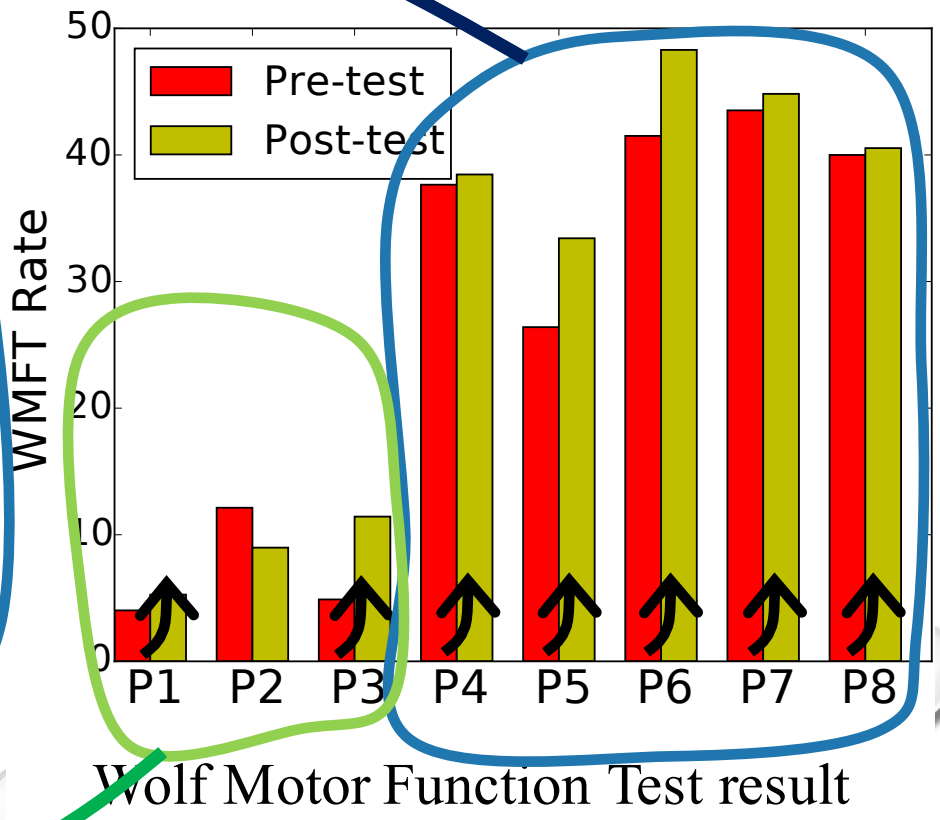
(e) Shoulder Angle Speed
(*raise-arm-side gesture*)

Experiment Analysis

- Observation 2: consistency. Trend & Scale.



(d) Hand Speed
(*raise-arm-side gesture*)



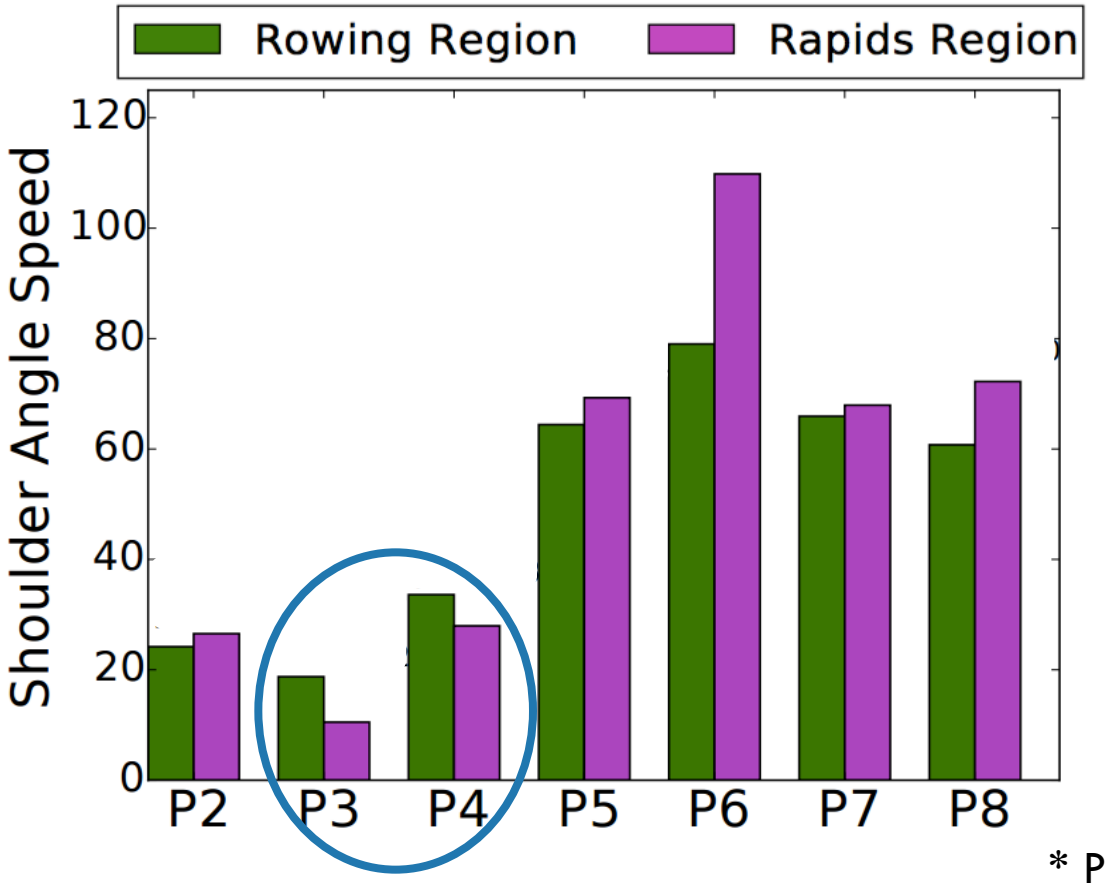
Wolf Motor Function Test result

Experiment Analysis

- Two-half comparison & Wolf Motor Function Test:
  - Very different metrics (game data analysis vs. lab test).
  - Show very consistent pattern of performance.
  - Kinematic measurement based on game data can serve as complimentary assessment (cheaper, more convenient).

Experiment Analysis

- Self-paced (Rowing Region) vs. fast-paced (Rapids Region) *.



(b) Shoulder Angle Speed

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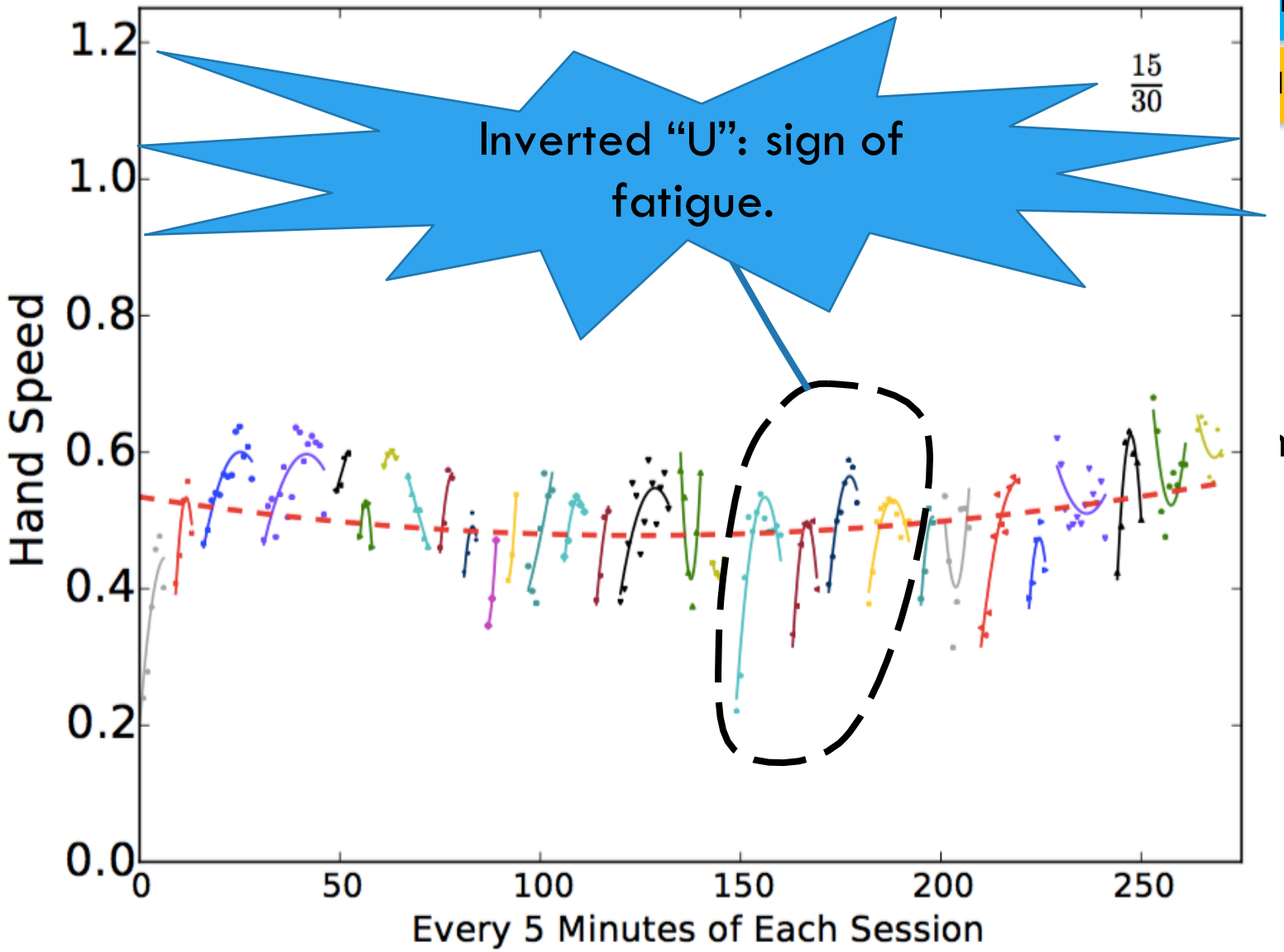
* P1 did not have different regions during gameplay.

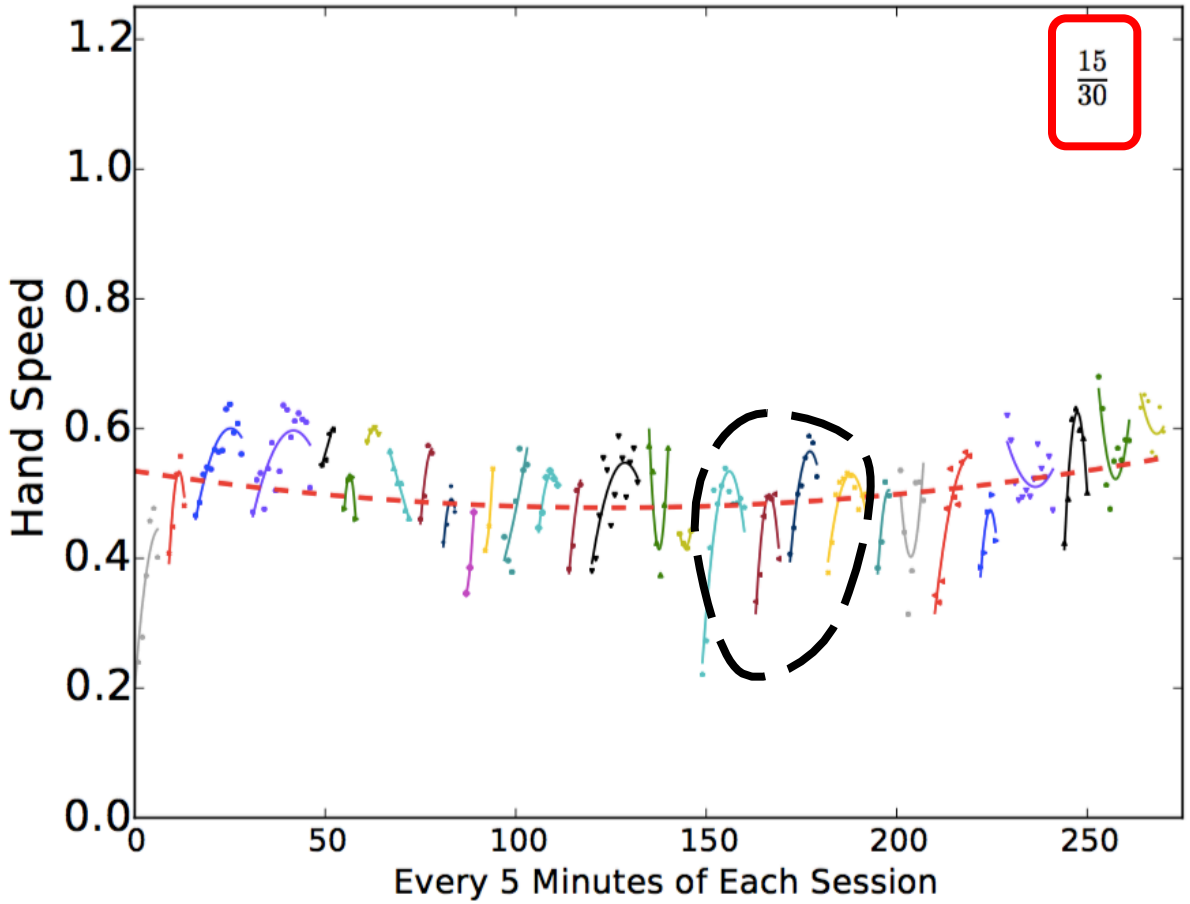
- C

session.



(d) P8

Experiment Analysis

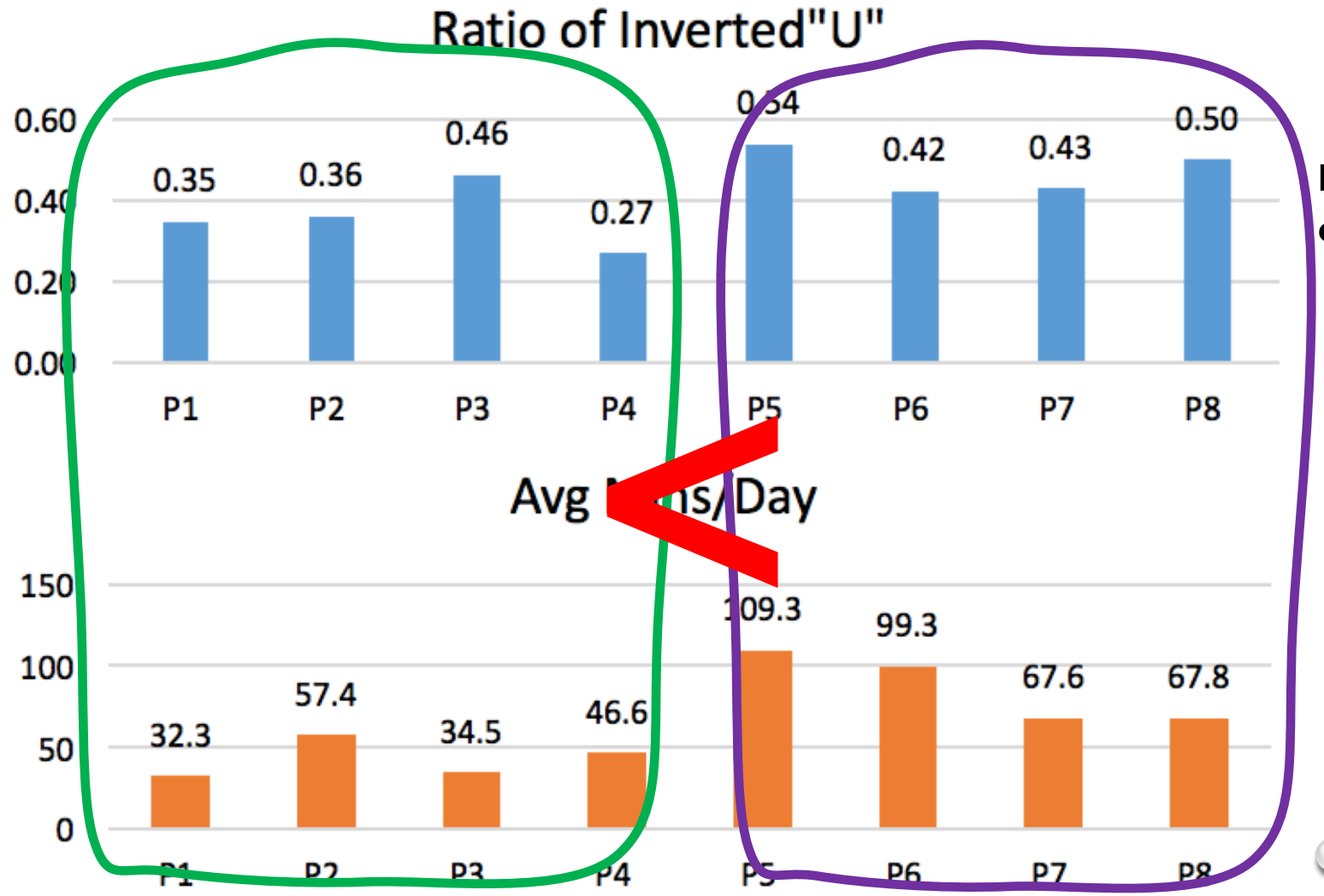


(d) P8

- Model inverted 'U' as a quadratic function (quadratic regression).
- Compute the ratio of inverted 'U' shape:

$$r = \frac{\#\text{ “}\cap\text{” } sessions}{\#\ sessions}$$

More gameplay time ➔ More inverted “U”



Pearson correlation coefficient:

$$\rho = 0.57$$

Conclusion

- Propose a data analytics framework to evaluate game-based rehab.
- Patients have obvious improvement but in different aspects. Consistent with standard WMFT in the lab.
- Reveal sign of fatigue, correlated with the gameplay time.

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Questions?

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