Variable-length accelerometer features and electromyography to improve accuracy of fetal kicks detection during pregnancy using a single wearable device

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bloomlife

Fetal Movement

Monitoring fetal movement during pregnancy is the **most practical and widespread method to assess fetal wellbeing**, one of the most important and complex tasks of modern obstetrics.

As birth outcomes are strongly linked to the development of fetal conditions during pregnancy, several techniques have been developed to monitor fetal movement up to date

Current Clinical Practice

Ultrasound: relies on high frequency sound waves being used to generate an image of the fetus and can be used only for a limited amount of time due to safety concerns. Require hospital stays or trained personnel.

Continuous cardiotocography: require cumbersome infrastructure and hospital visits, also involving trained personnel to set up the device and process the produced information.

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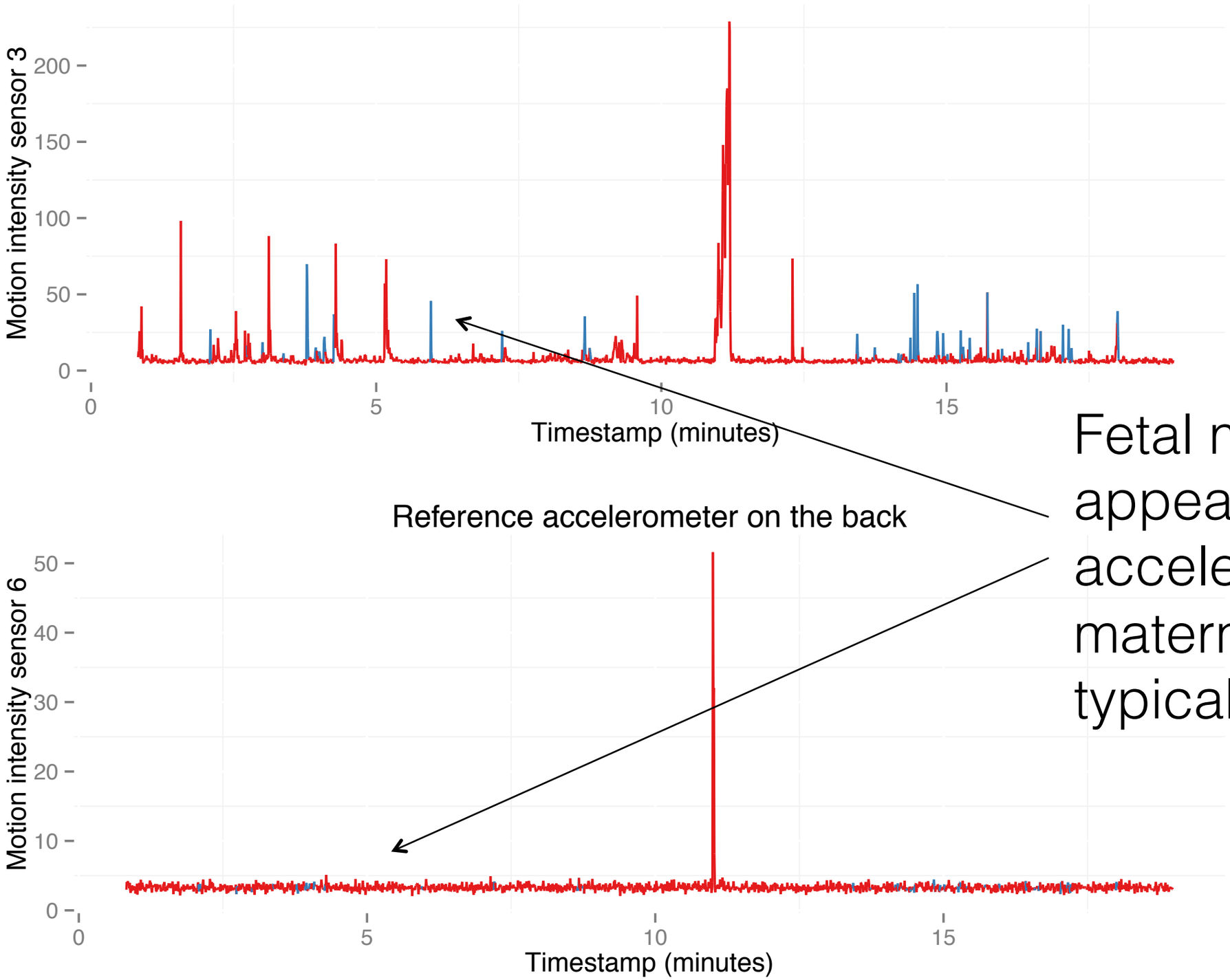
-> Only sporadic checks in the hospital environment

New Passive Solutions

Accelerometers: Most studies to date involved one single accelerometer placed on the abdomen and reported rather low sensitivity and specificity.

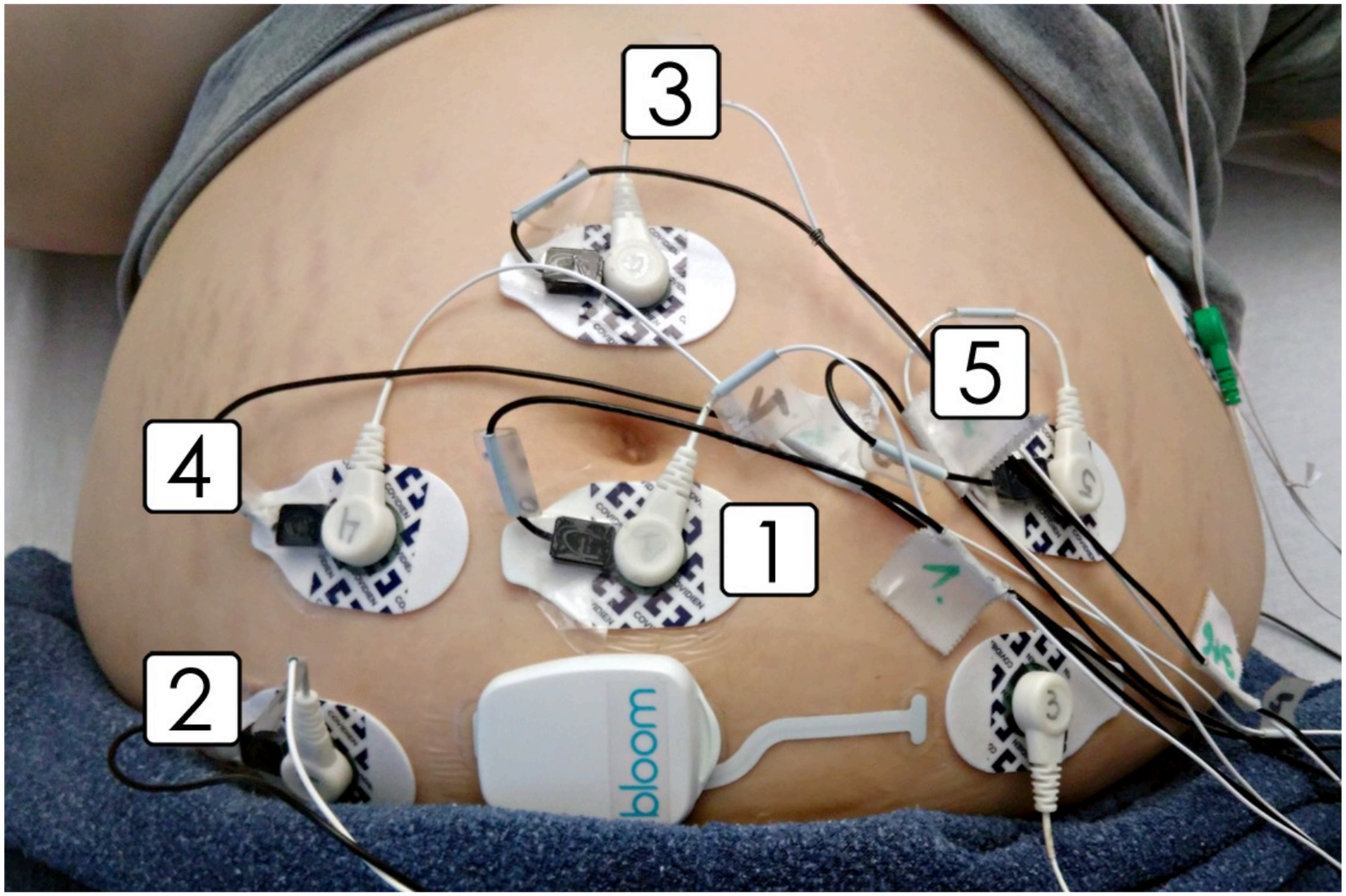
Other researchers added a **reference accelerometer** with the rationale that by monitoring maternal movement artifacts using an accelerometer placed outside of the abdominal area, fetal movement should be separable from maternal movement and therefore detected more accurately.

New Passive Solutions: Reference Accelerometer



Fetal movements do not appear on the reference accelerometer, while maternal movements typically do

New Passive Solutions



-> Promising results, still limited practical applicability

Single Sensor

Performance: consistently lower with respect to multiple sensors and reference accelerometers outside of the abdomen area. **Higher false positives** (harder to discriminate between maternal movements / artifacts and fetal movements)

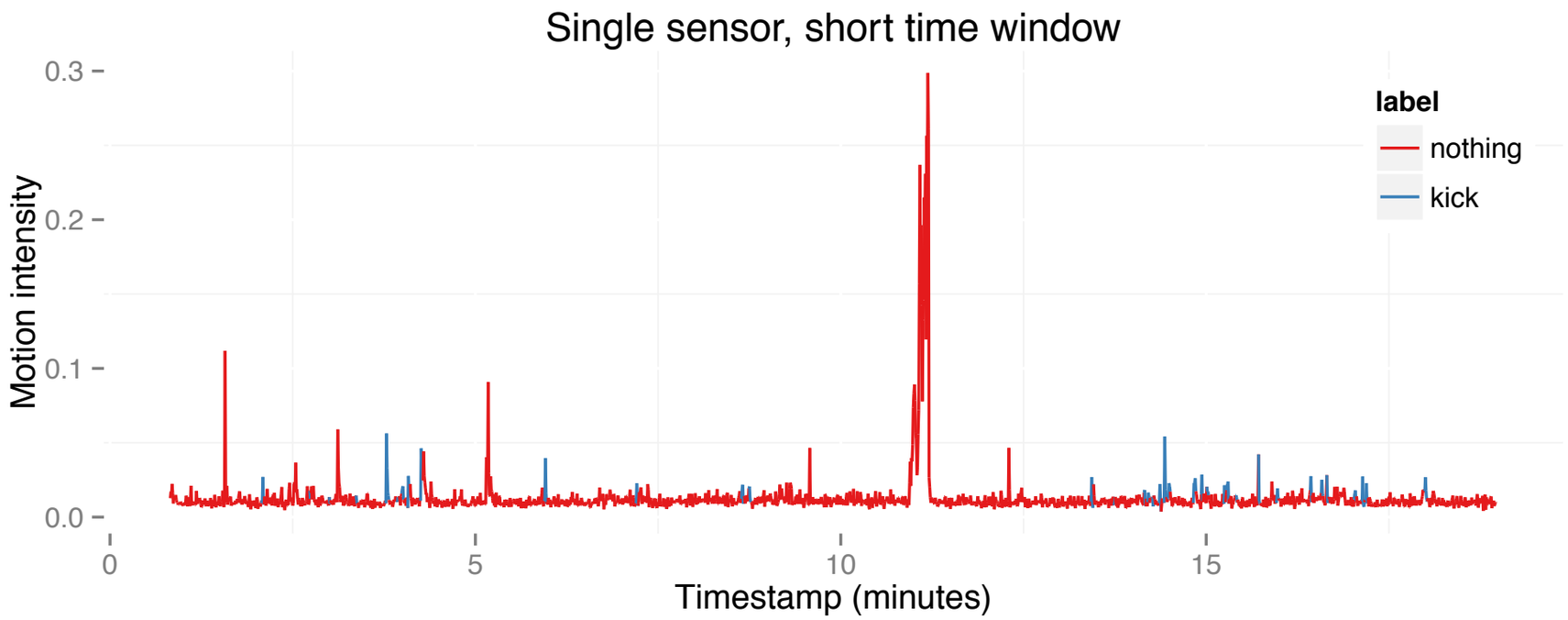
How do we reduce false positives?

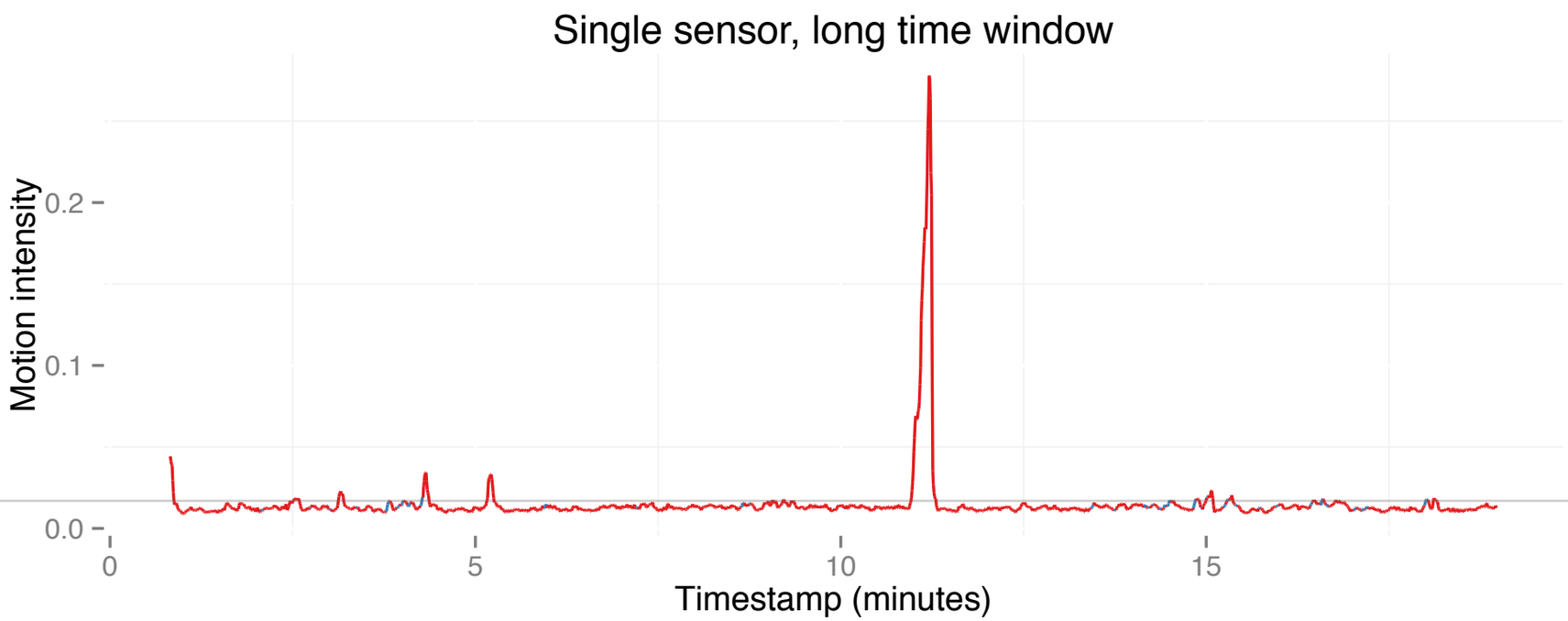
Variable-Length Accelerometer Features and Physiological Data

The proposed techniques **aim at reducing false positives** by providing more contextual information related to maternal movement while still using a single wearable device to cope with the absence of a reference accelerometer or a more obtrusive system.

To account for **different dynamics in maternal and fetal movement**, we computed features over two time windows of 0.5 and 4 seconds. The rationale is that short fetal movements should be averaged out over longer time windows but captured over short ones, while maternal movements should appear over windows of both durations.

Variable-Length Accelerometer Features and Physiological Data





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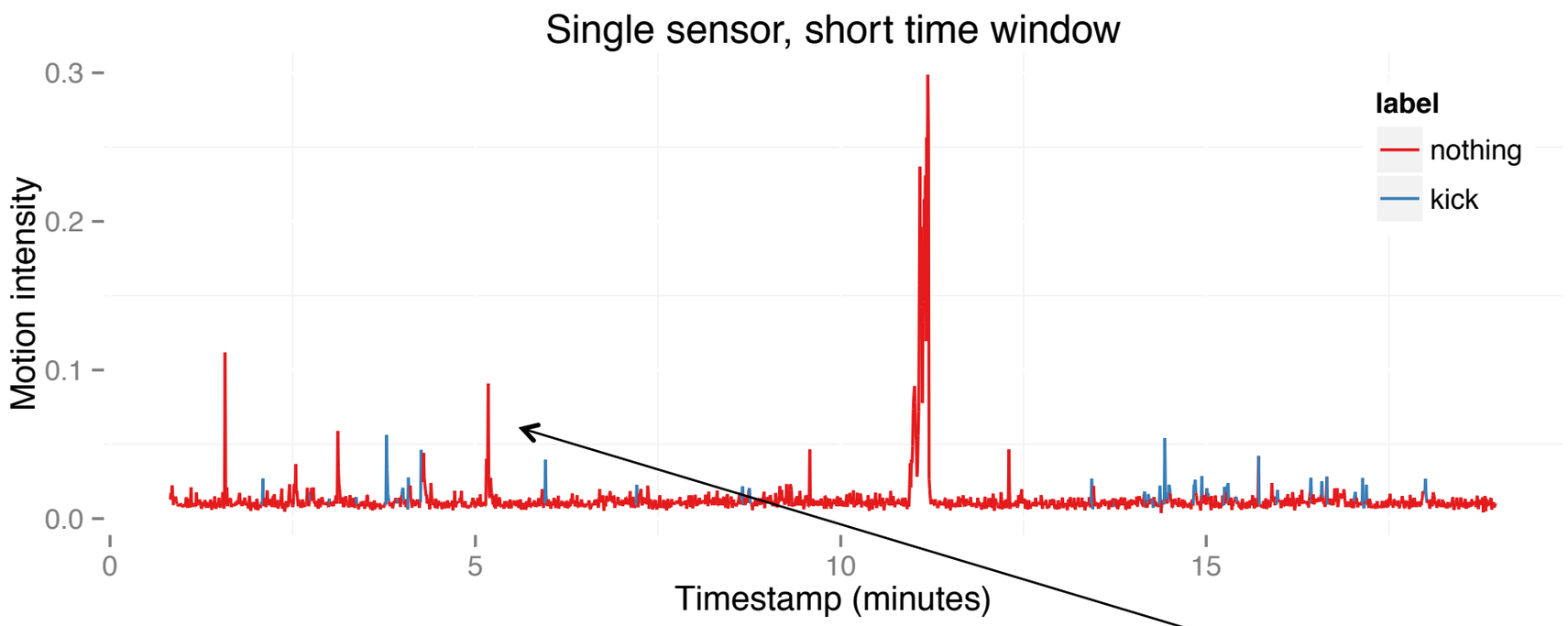
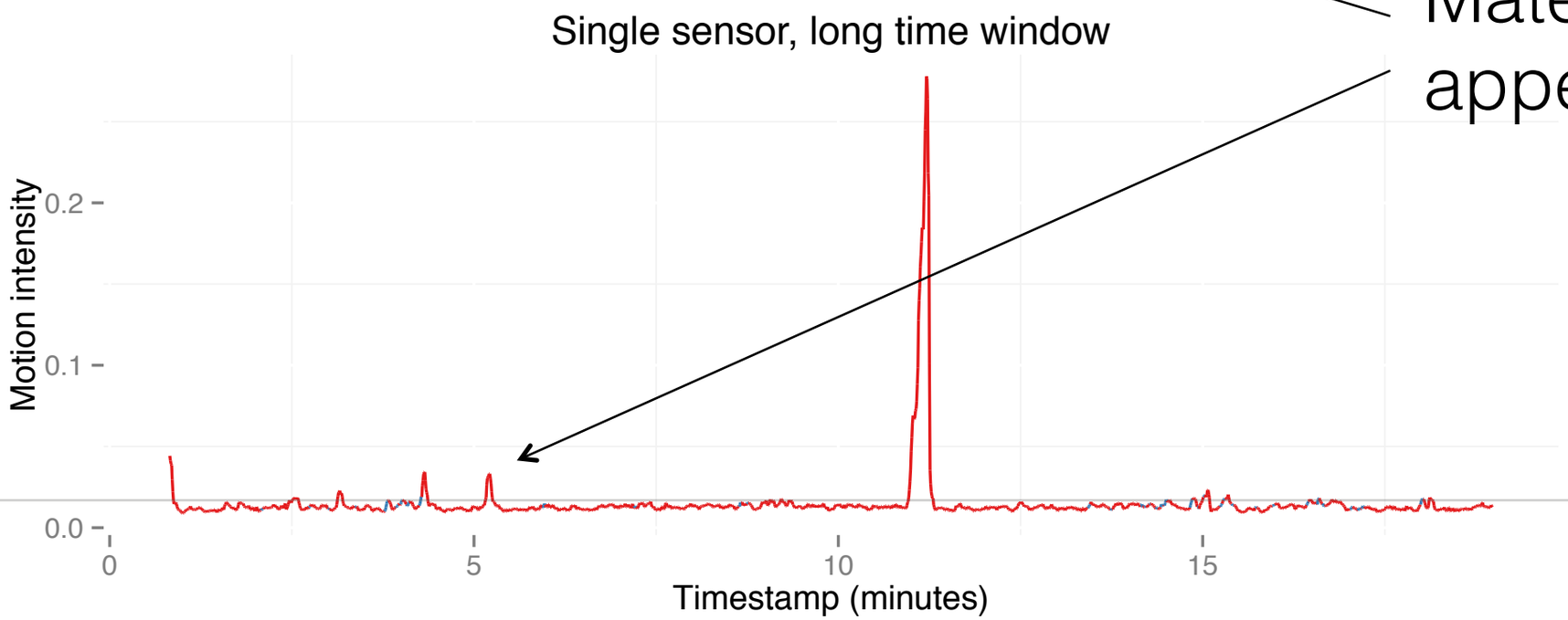


Maternal movements appear on both traces



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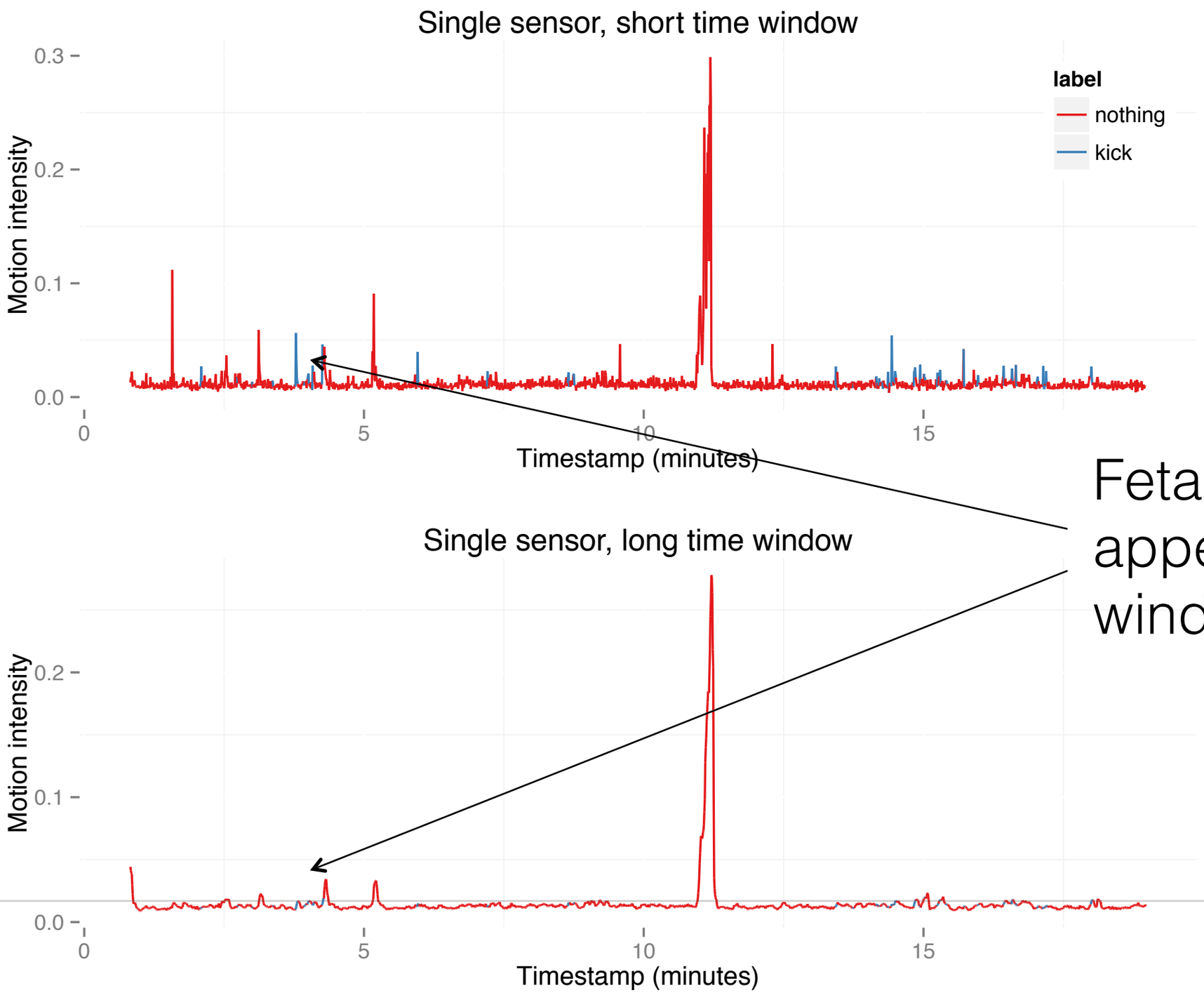
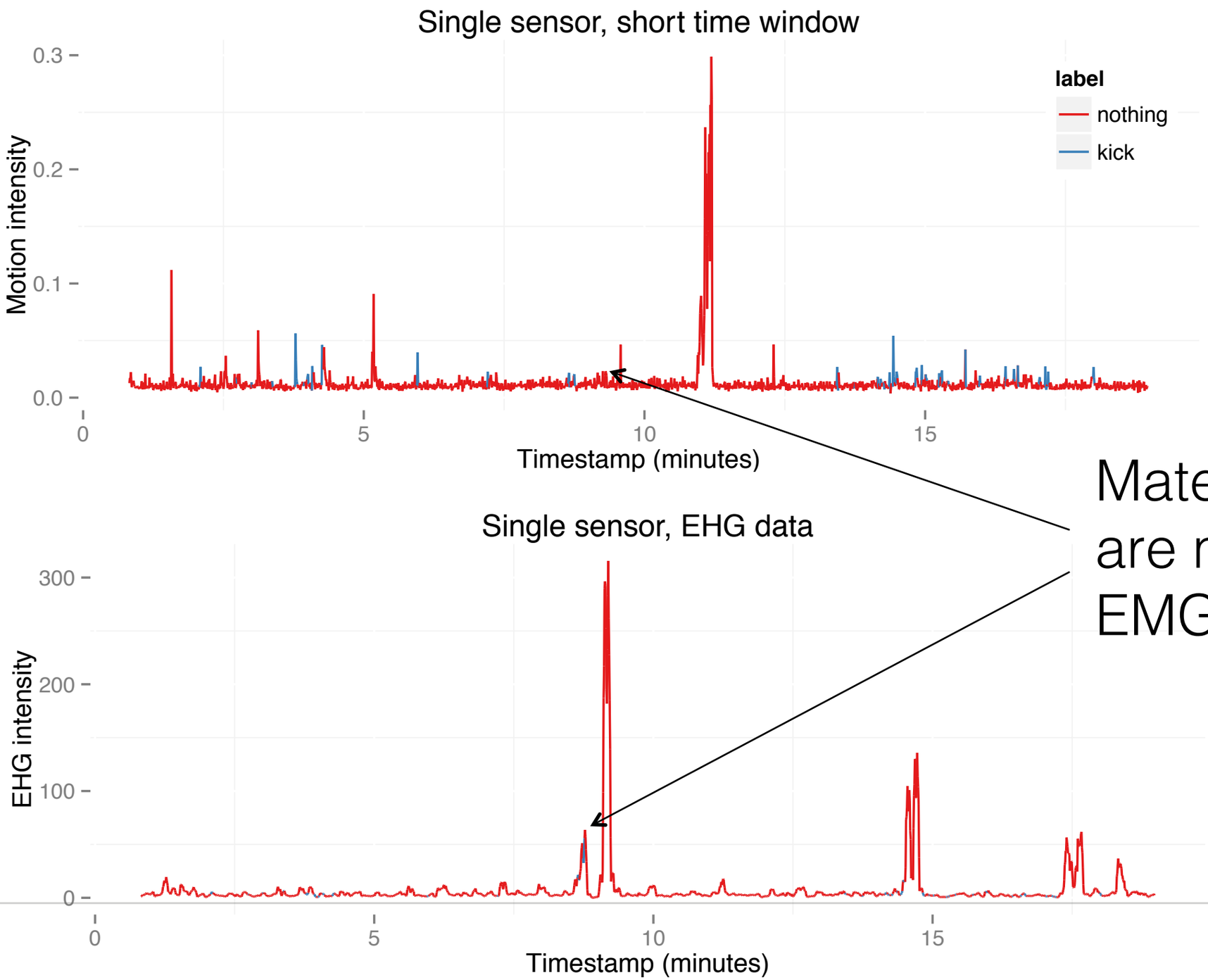


Fetal movements appear on the short window trace only

Variable-Length Accelerometer Features and Physiological Data



Maternal movements are more likely to trigger EMG activity

Study Design

Twenty-two recordings of about 60 minutes duration were collected from 22 pregnant women at different gestational ages during pregnancy, all from week 30 onwards.

Fetal movements ranged between 0 for inactive babies to 315 for hiccups cases.

Measurements were performed using two devices. A research version of the Bloomlife wearable device, configured to acquire two channels EMG at 4096 Hz and triaxial accelerometer data at 128 Hz and the TMSi system including 6 accelerometers, five placed on the abdomen and one on the back.

Features, Classifier and Class-Imbalance

Features: low-complexity time domain features (mean, standard deviation, interquartile range, correlation between axis, sum, min, max and magnitude).

Classification: Random forests. We set the number of features to select at each iteration to the square root of the total number of features.

Class imbalance: small number of kicks with respect to the total available data. The optimal ratio between reference class (kicks) and majority class (non-kicks) was determined by cross-validating and optimizing for F-score. Our optimal balance included all data from the minority class and one fifth of the majority class data

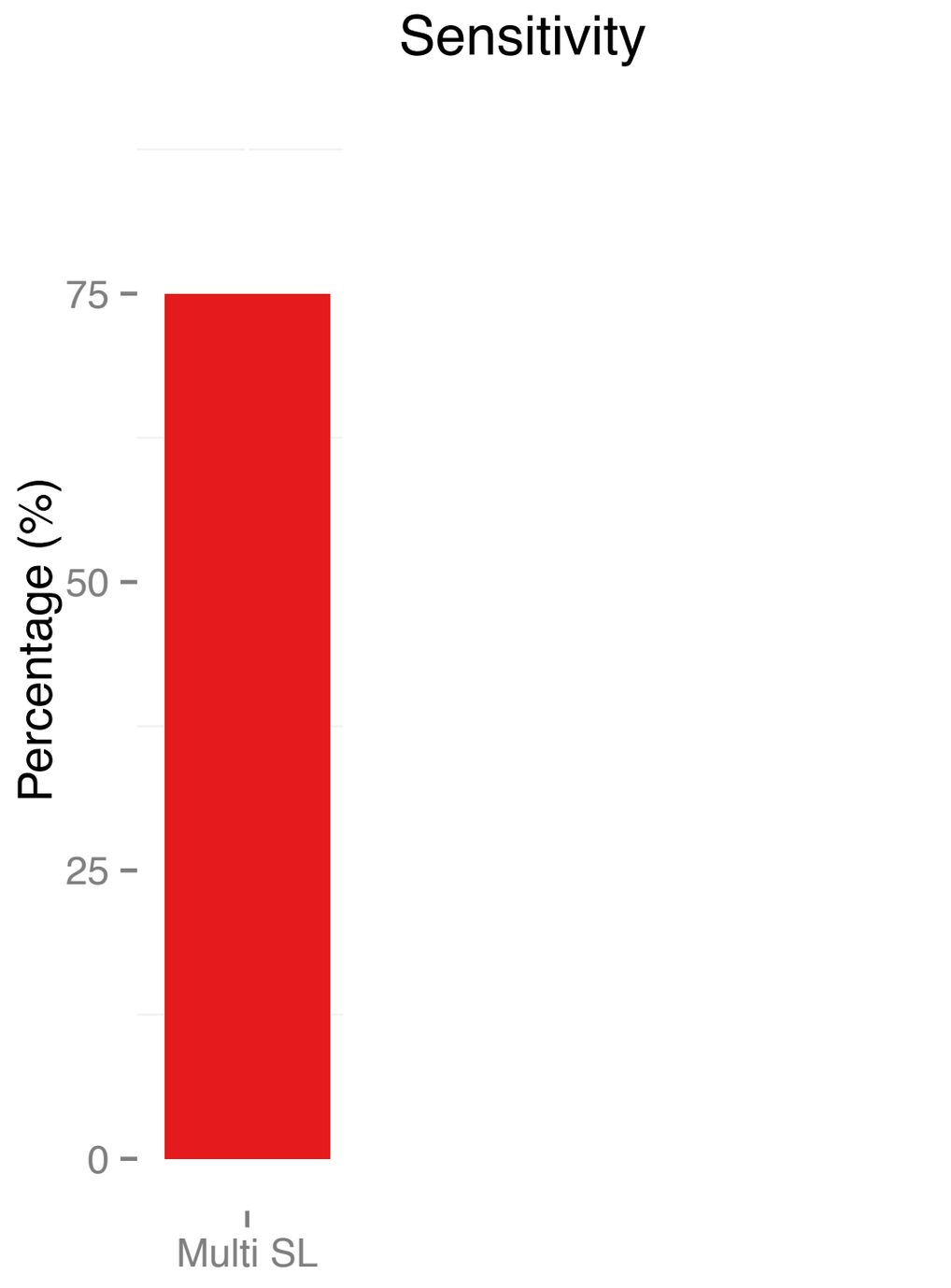
Comparisons and Cross-Validation

We compared four feature sets associated to the two systems used in this study in order to highlight the impact of the novel methods proposed to improve accuracy of a single wearable device:

1. TMSi (6 accelerometer system) and variable-length features.
2. Bloomlife (single wearable sensor) and features computed over a **short time window only** Bloomlife and features **computed over both short and long time windows**.
3. Bloomlife and features computed over both short and long time windows plus **EMG features**.

All models were derived and validated using leave one participant out cross-validation

RESULTS: SENSITIVITY



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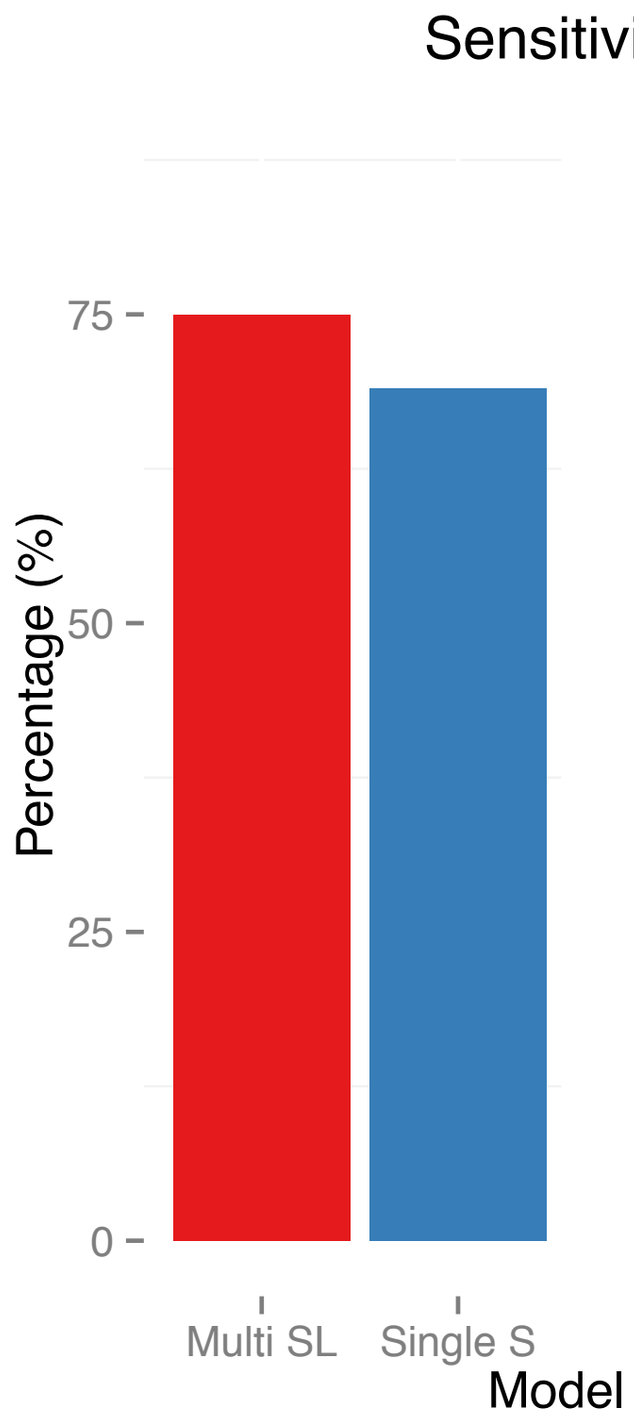

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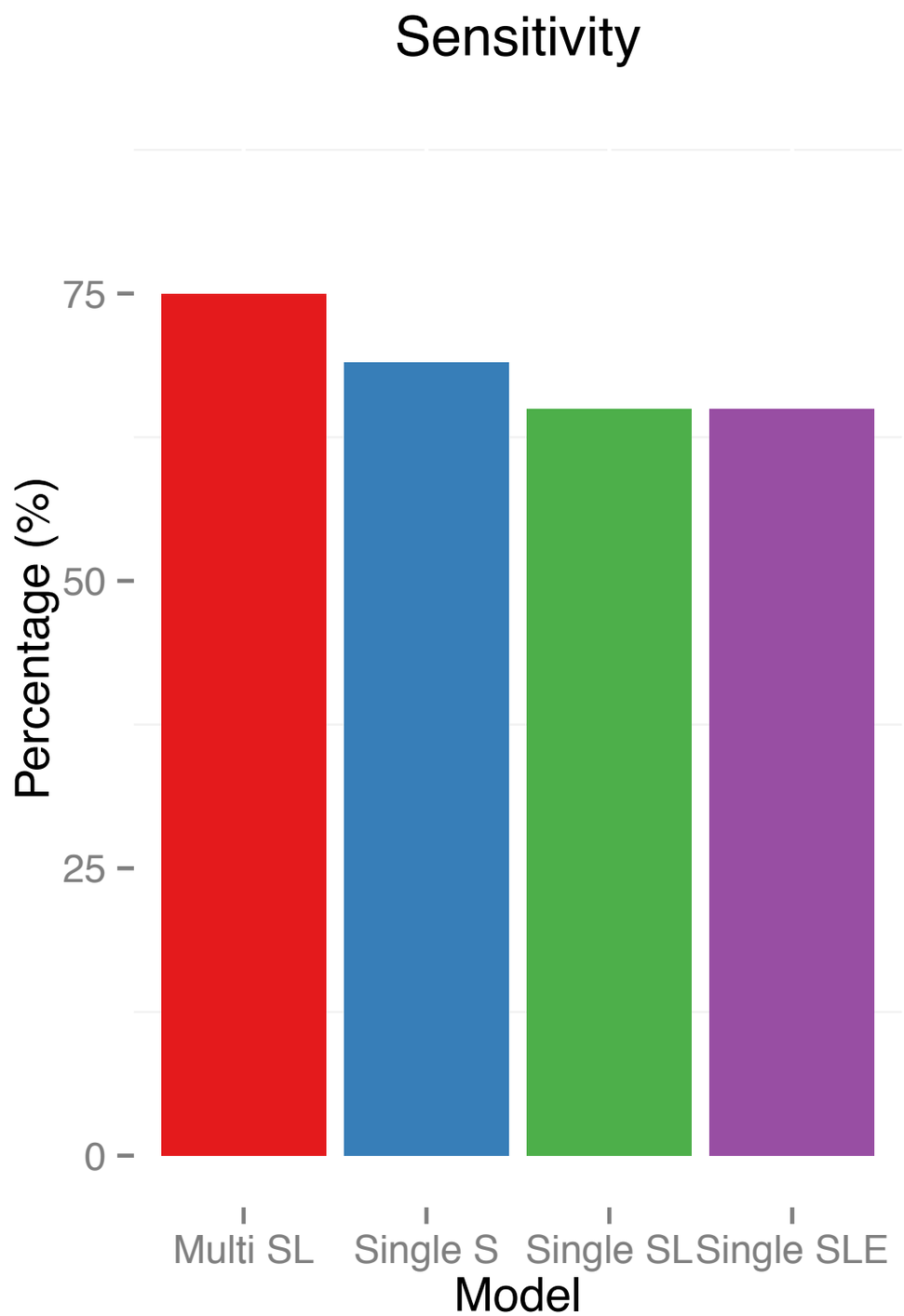
Sensitivity does not change much by introducing variable-length and EMG features as the aim of these features is to reduce false positives.



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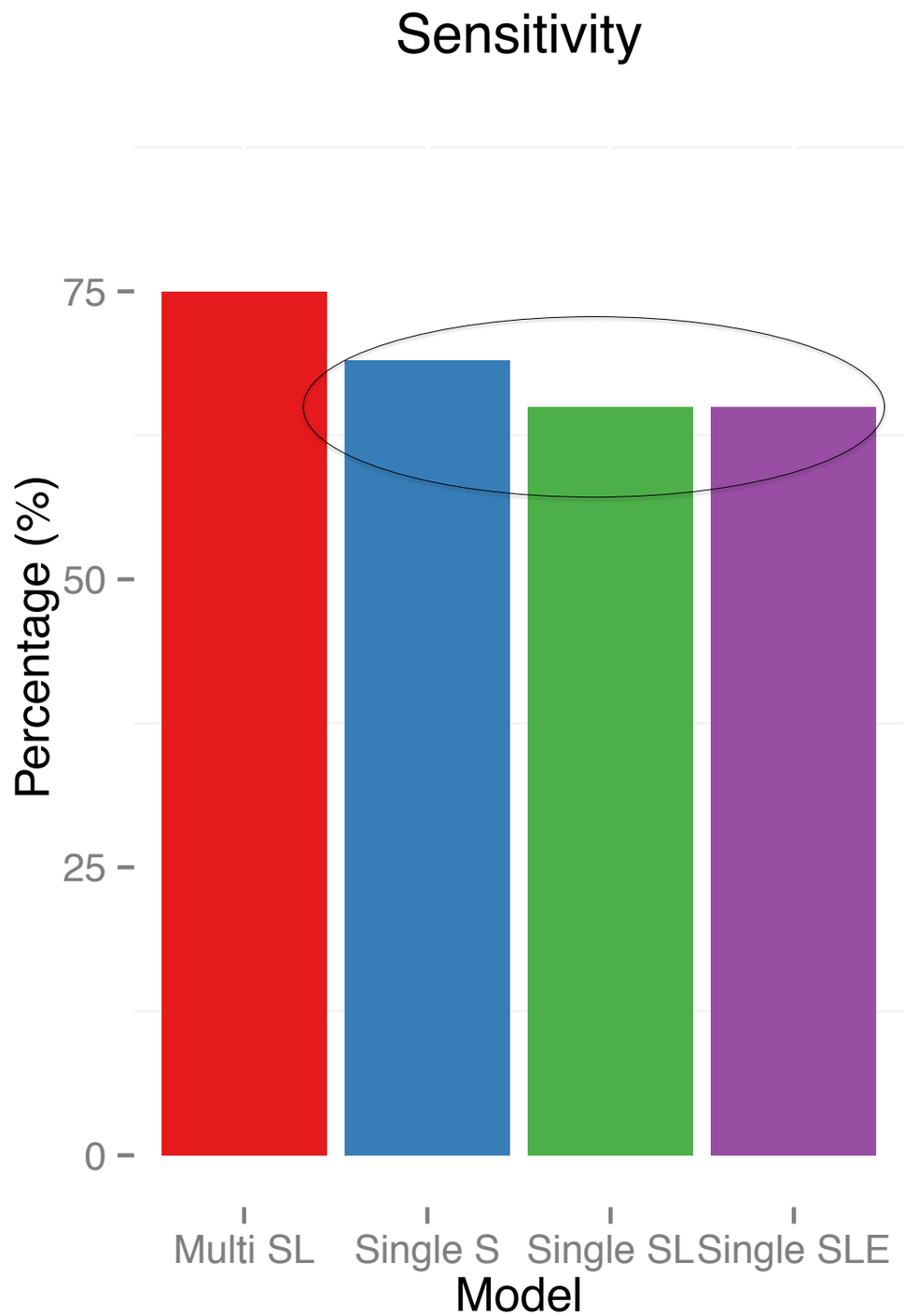

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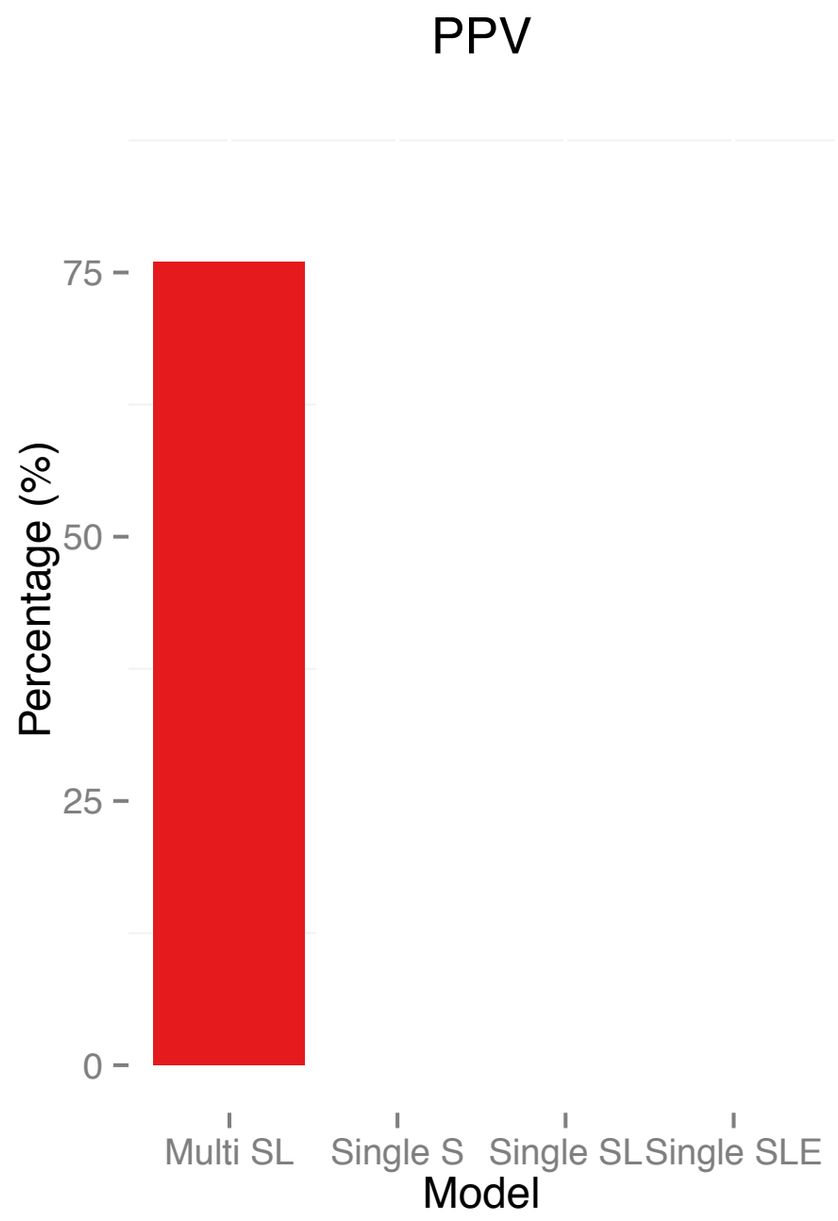

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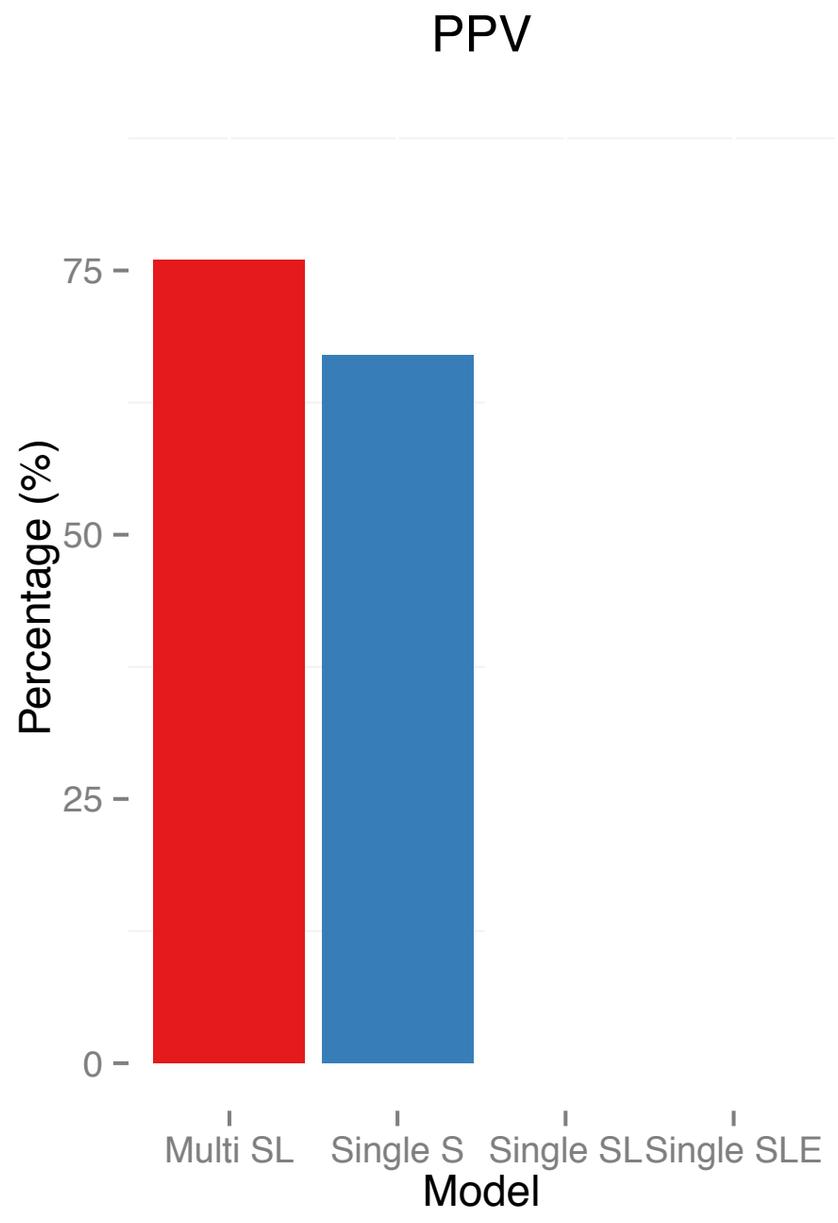

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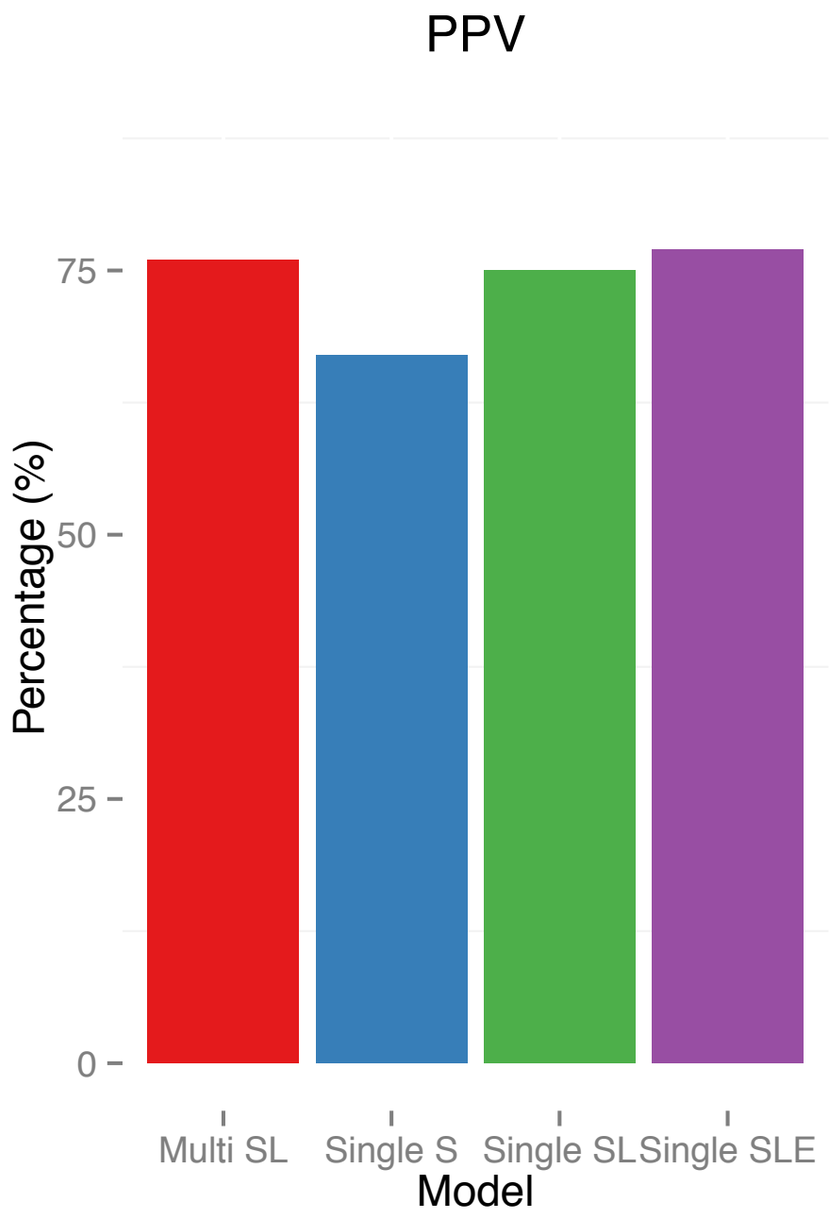

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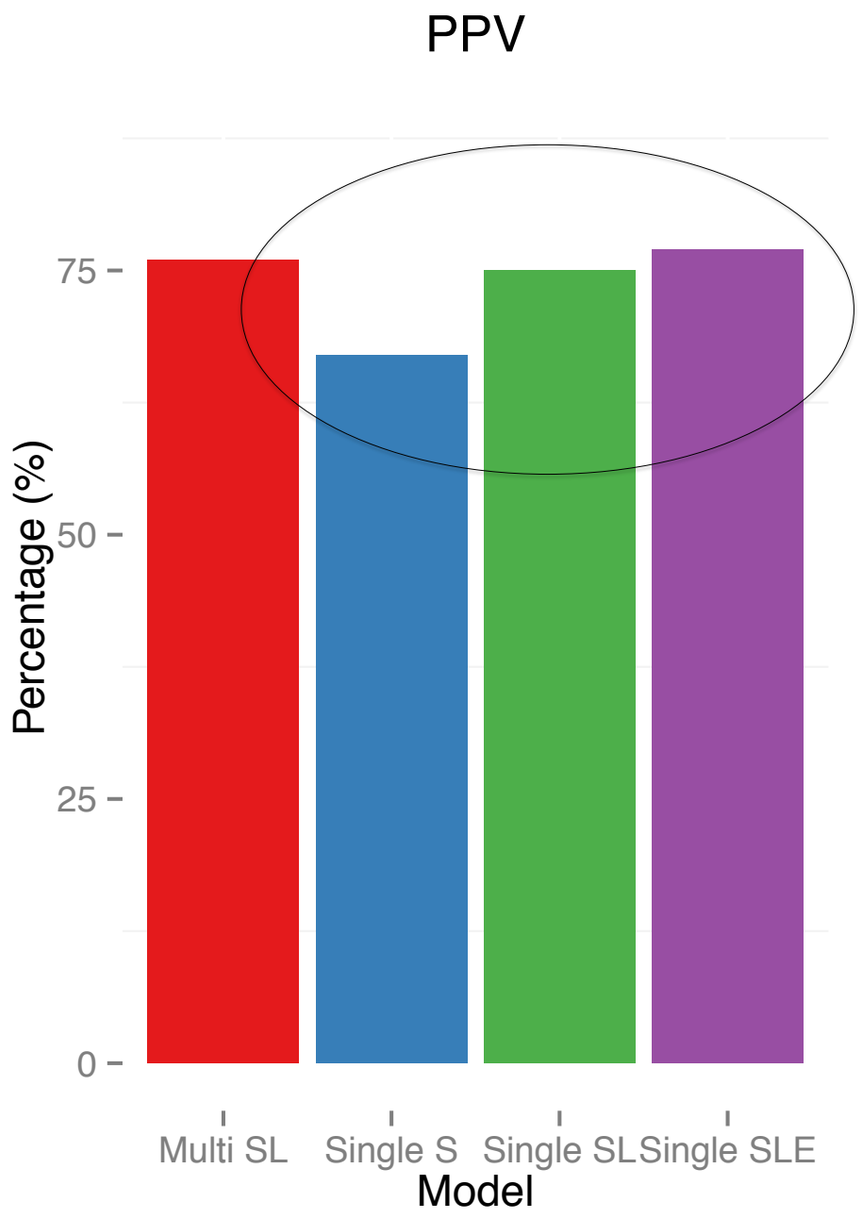
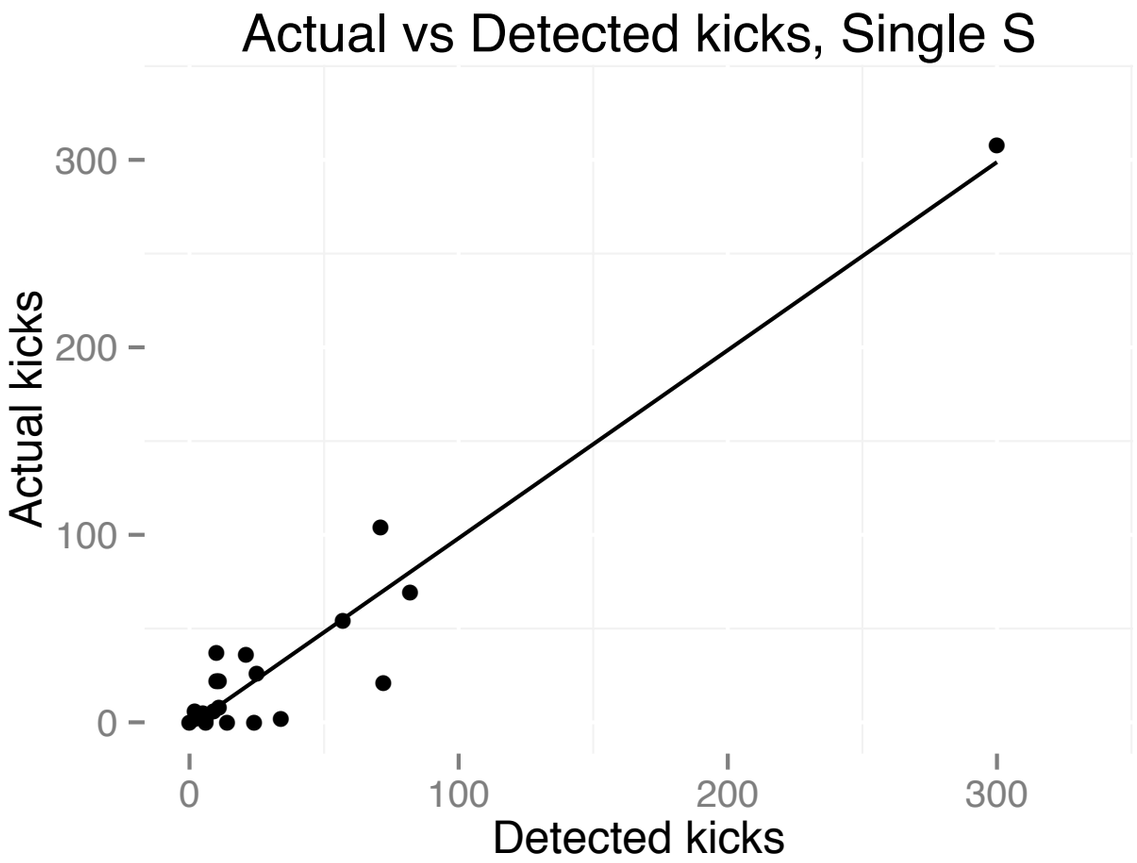
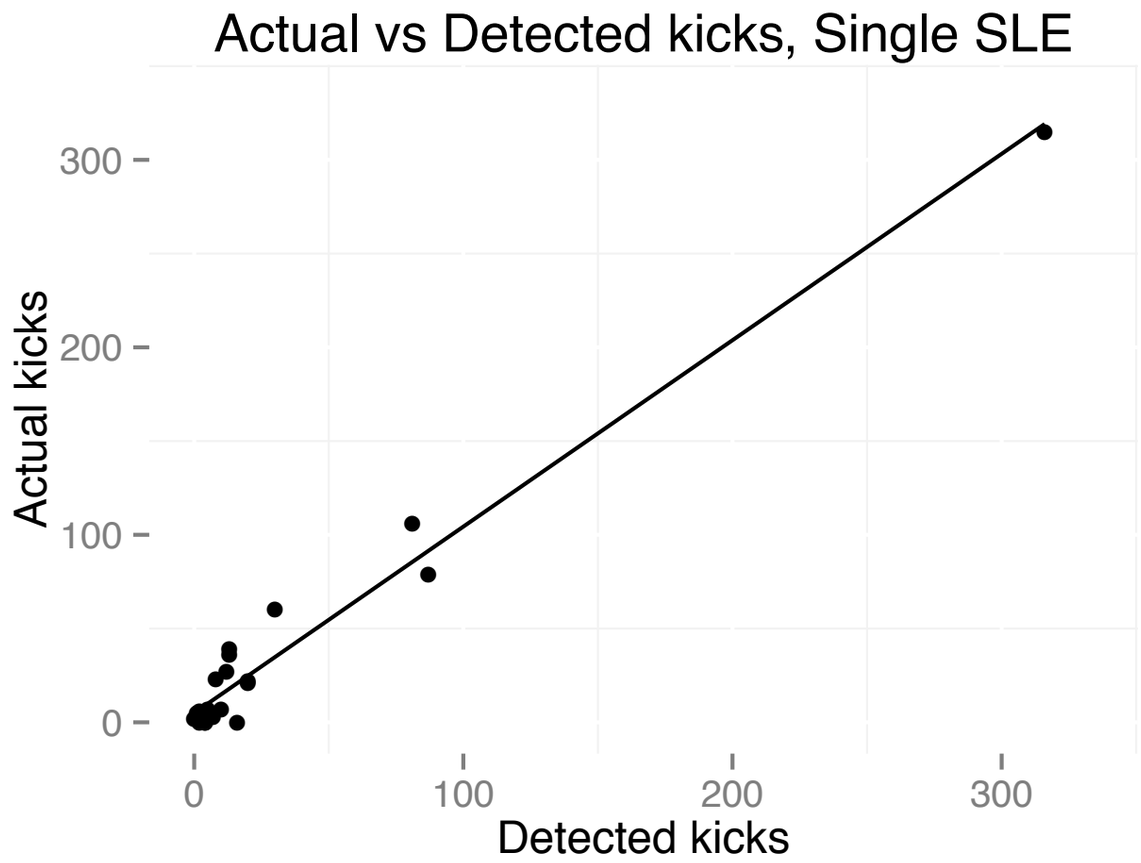


Results: Total Number of Kicks per Recording





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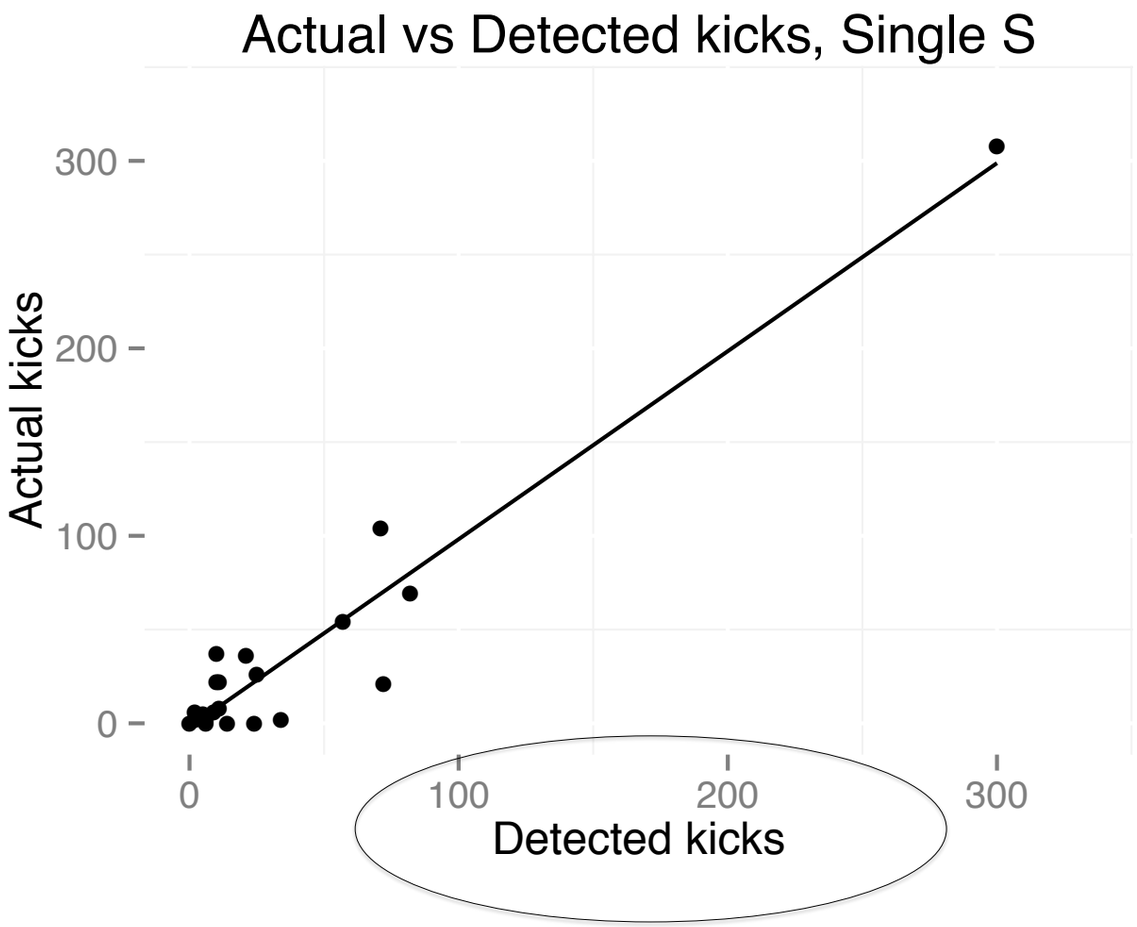

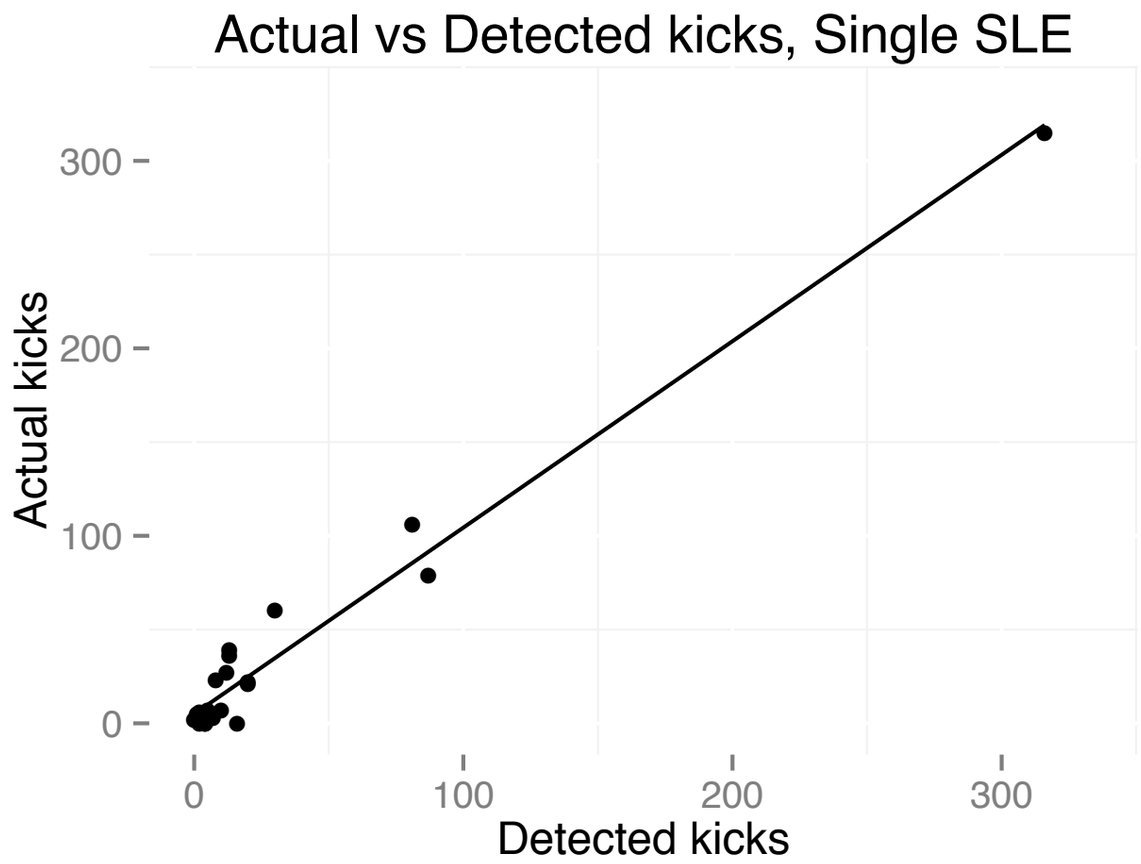

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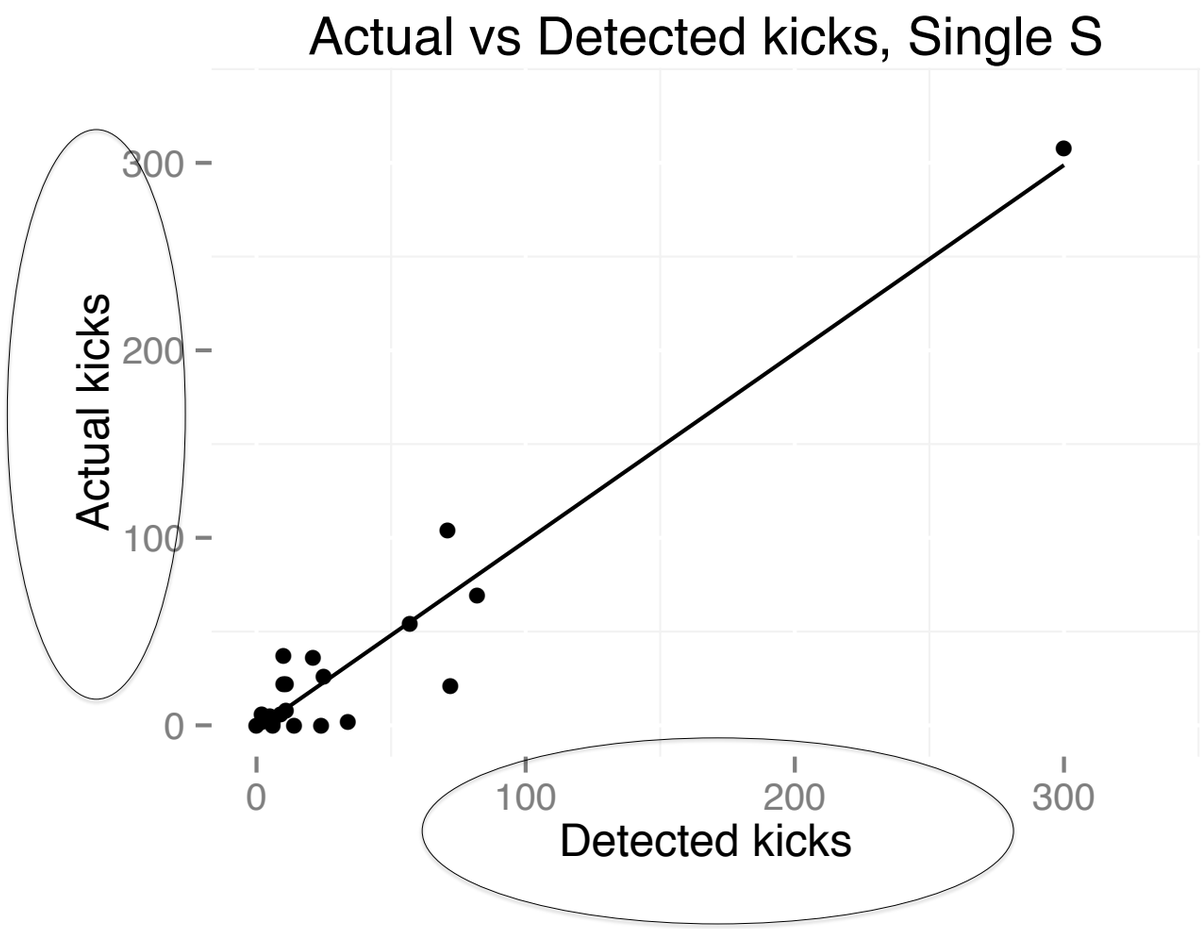

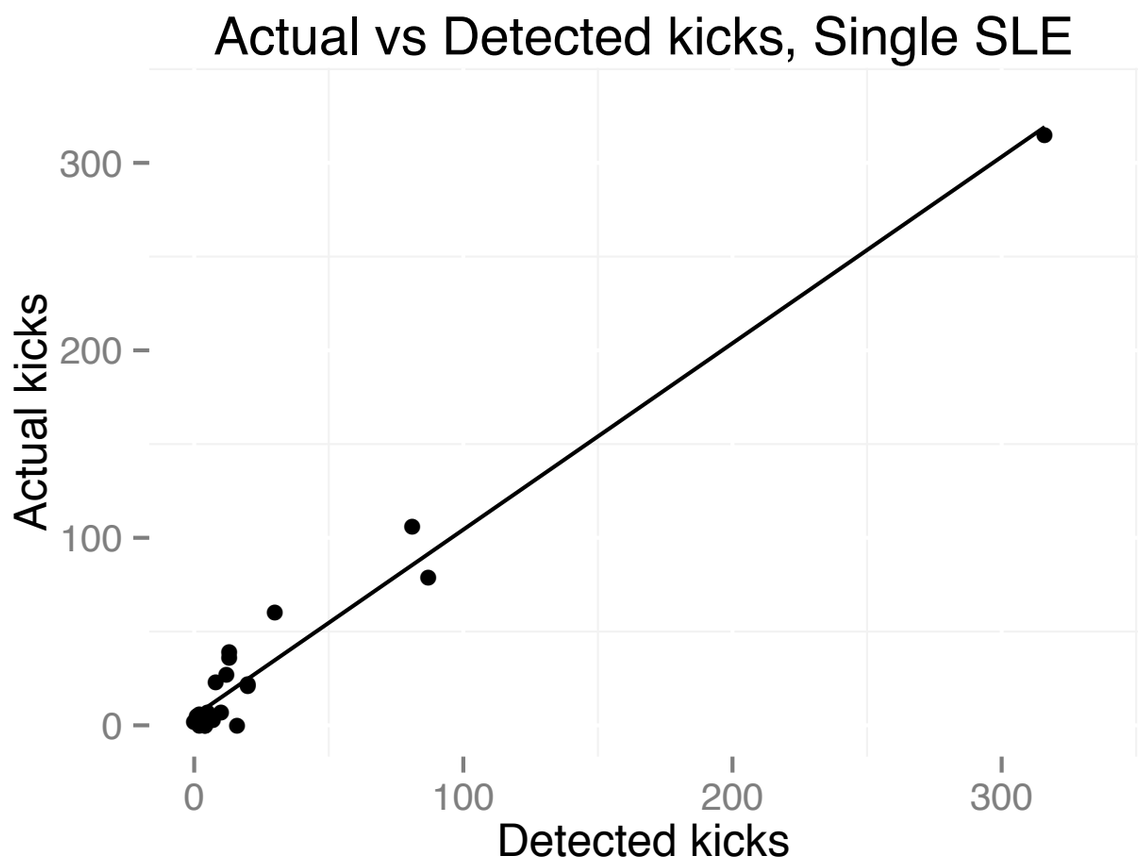

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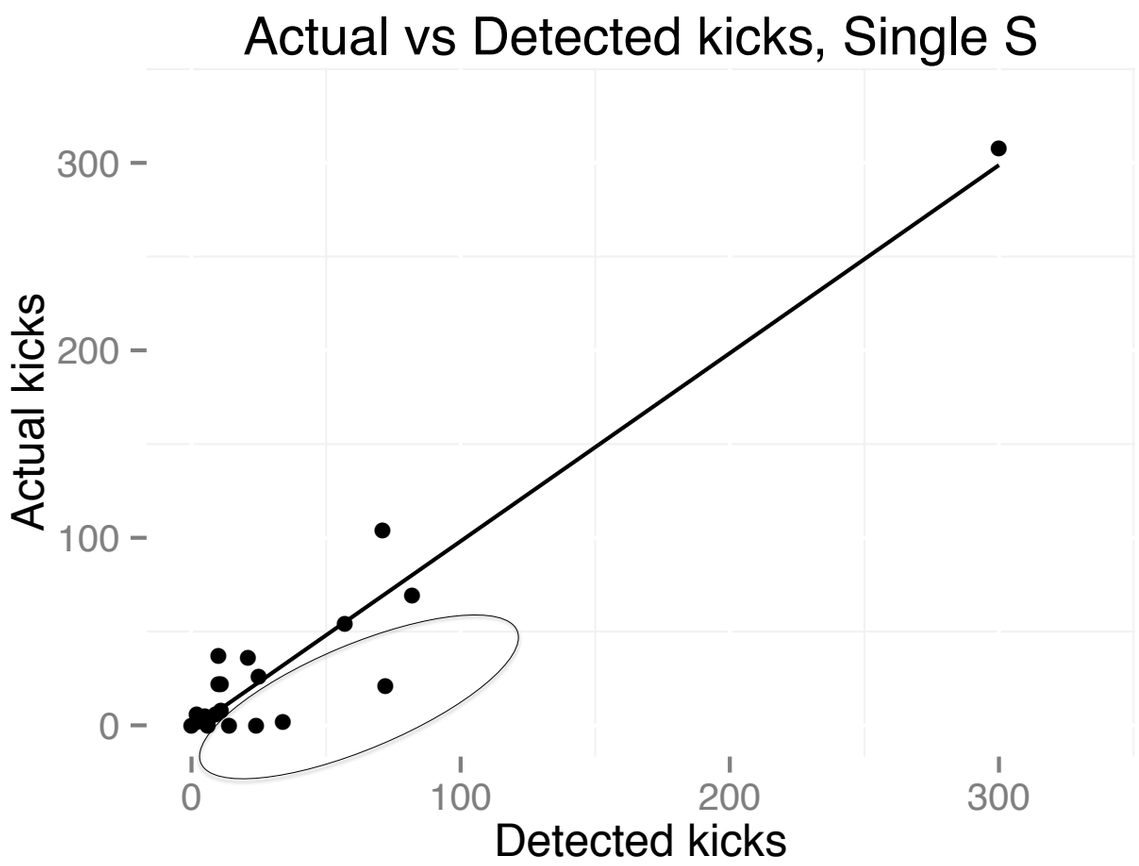

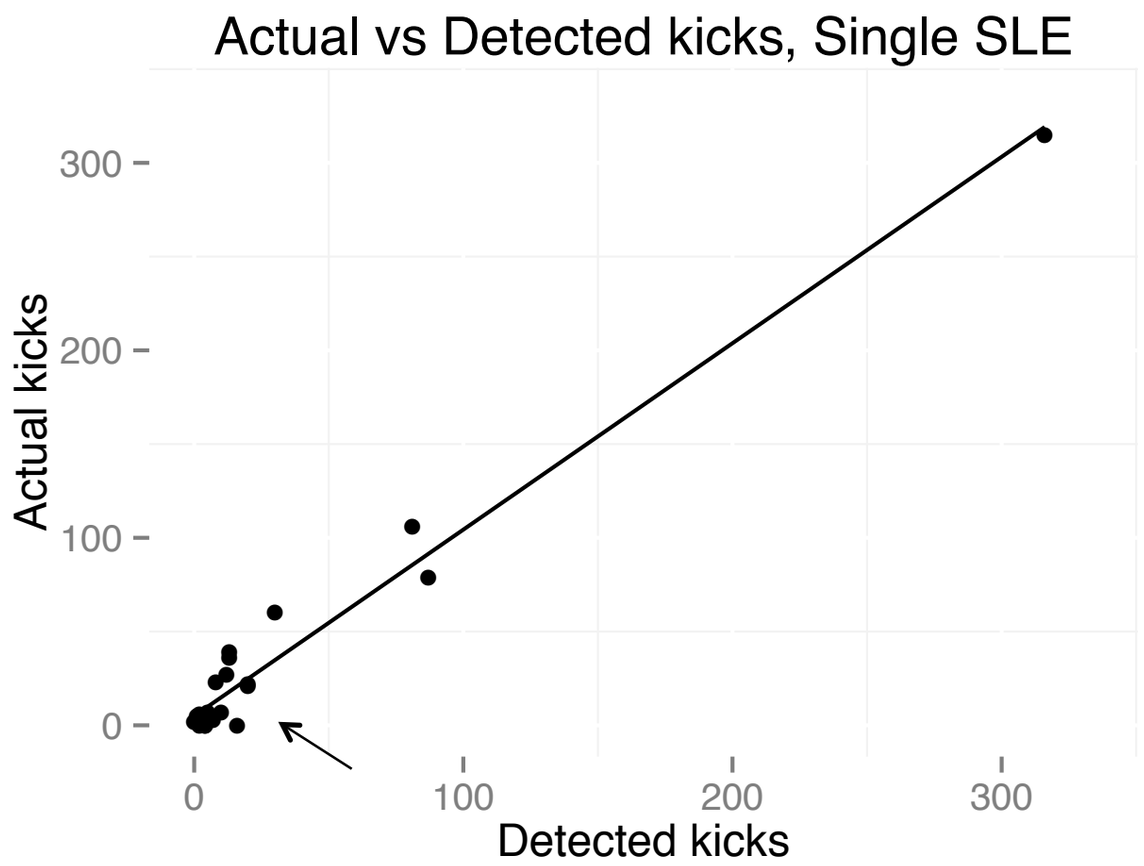

Less overdetections at the recording level as well

CONCLUSIONS

We proposed a method to improve the accuracy of fetal kicks detection during pregnancy using a **single wearable device** placed on the abdomen.

Including variable-length accelerometer features, short fetal movement is averaged out over longer time windows but captured over short ones, while maternal movements of greater intensity appear over windows of both durations. As a result, a single wearable device can be used to better discriminate fetal and maternal movement without the need for a reference accelerometer (**11% improvement in PPV**).

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Thank you

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