MOTION DATA TEAM SEMESTER REPORT

I. Summary

The motion data team consists of Julie Deng, Yiming Ding, and Suman Tripathy. We are working with the motion data in experiments conducted in Taiwan up to March 18th. The data set includes 10 healthy kids and 10 ADHD kids, among which 2 ADHD kids and 1 healthy kid are missing hand and foot data.

Before any analysis, we:

1. Visualized head position and rotation data;
2. Applied a 4th order Butterworth Low Pass filter to all raw data. But then found that the filter does weird things to head rotations and IMU sensors need further fusion, so the result obtained from the filter is ignored;
3. Used Kalman Filter to do gravity compensation for hand and foot IMU sensors.

Then we extracted 7 motion features features from head, hand and foot data for 20 subjects:

a. Number of head rotations
b. Number of small head movements
c. Trajectory head path length
d. Area under acceleration curve for hand
e. Area under acceleration curve for foot
f. Percentage of time over an acceleration threshold for hand
g. Percentage of time over an acceleration threshold for foot

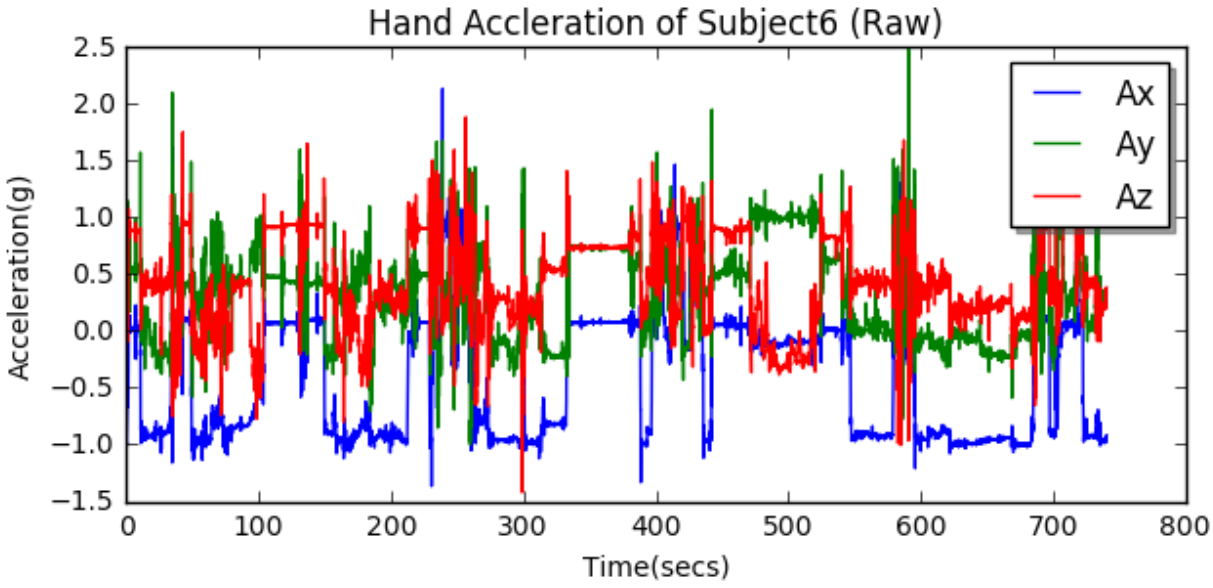
We also produced a time series of standard deviations of the acceleration measured by accelerometer in hand and foot.

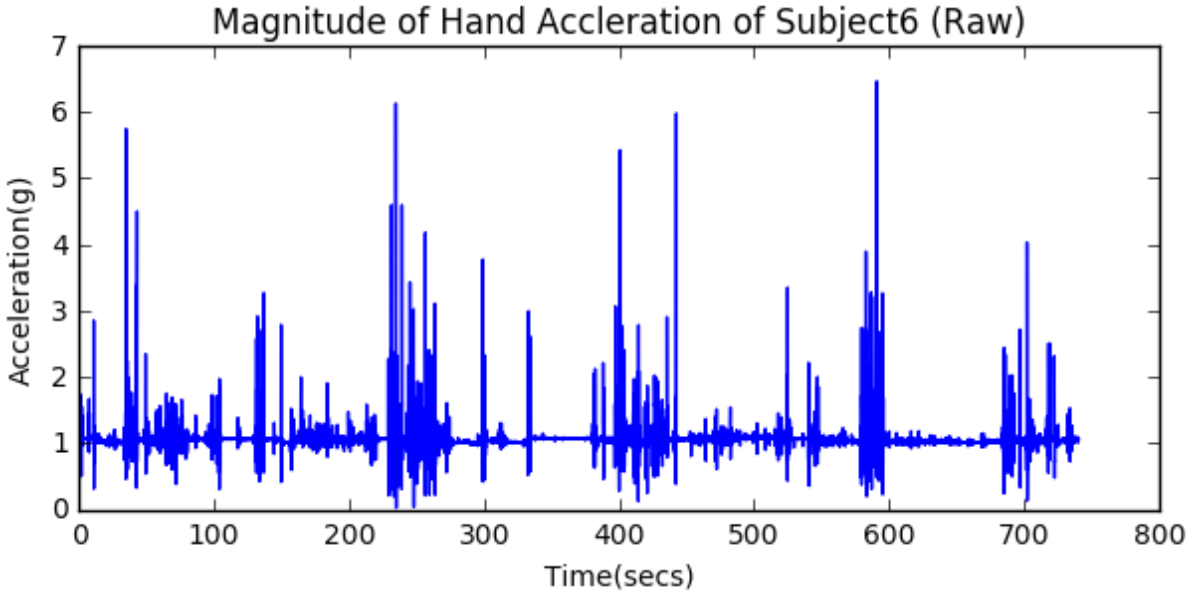
Finally, we did event related analysis on motion data. We compare the motion of the subject during distraction and non distraction period by extracting those motion features at time when distraction appears and at time right before distraction.

II. Method and Results

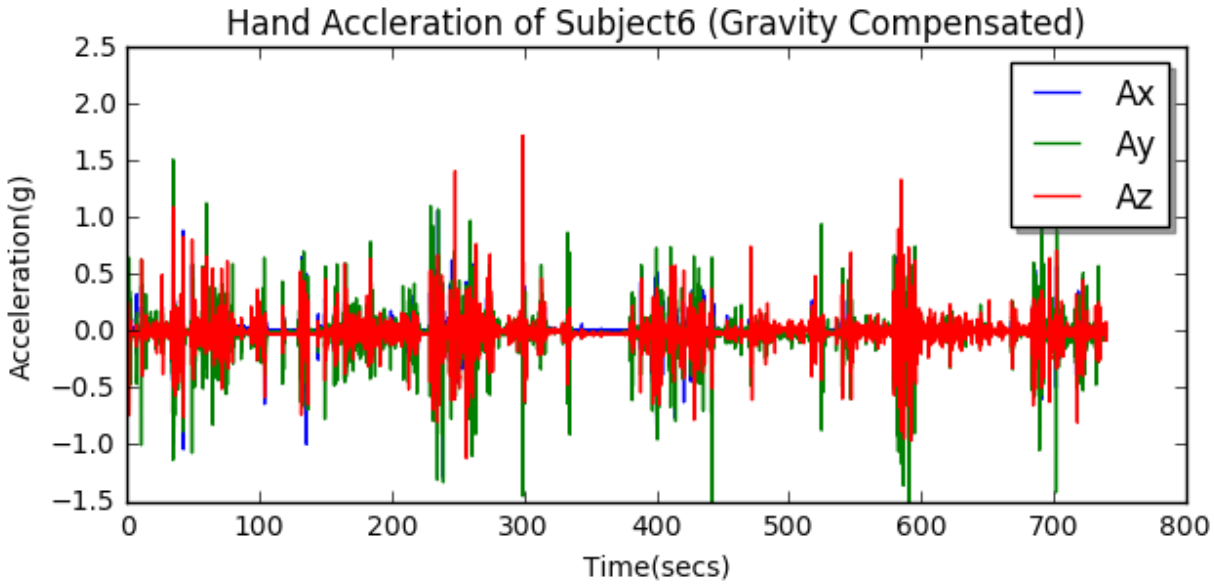
A. Gravity Compensation

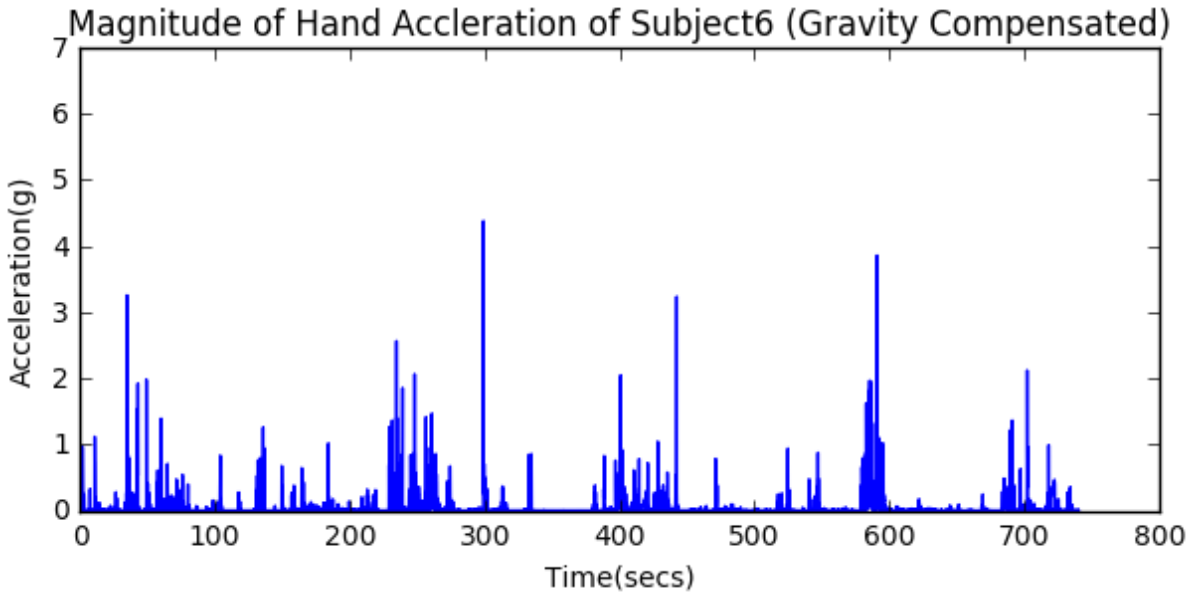
Here is an example of the uncompensated hand accelerometer data from subject 6.





As we can see in the second figure, the baseline of the magnitude of hand acceleration (magnitude is always positive) is centered around 1g (9.8 m/s/s), which is exactly the acceleration of the gravity. We are only interested in the acceleration that is generated not by gravity. So after gravity compensation, the acceleration looks like this:





We notice that the baseline of the magnitude is 0 instead of 1. This implies that we have (roughly, will talk about it section 3) got rid of the influence of gravity and only keep the acceleration generated by the hand motion.

B. 3 Motion Features from Head

1. Number of Head Rotations

A degree change over 300 in each dimension is considered as a rotation. We count number of rotations in each dimension (RotX, RotY and Rot Z) and add the three numbers up to create a single variable that represents the total number of head rotations.

	Unfiltered Healthy	**Unfiltered ADHD**
1	239	188
2	122	59
3	82	493
4	146	211
5	276	203
6	131	205
7	3	92
8	22	157
9	69	150
10	6	160
Avg	**109.6**	**207.3**
t-stats **P Value**	**-1.7371** **0.1003**	

2. Number of small head movements

Count changes in head position that are greater than 1 mm within 1 second.

	Filtered Healthy	**Filtered ADHD**
1	4216	2058
2	455	166
3	1066	7211
4	1487	581

5	3678	33
6	967	384
7	143	266
8	240	399
9	725	2566
10	47	310
Avg	**1302.4**	**1397.4**
t-stats **P Value**	**-0.1130** **0.9114**	

3. Path length of changing head position

Euclidian path length of head position

	Filtered Healthy	**Filtered ADHD**
1	42.46	27.62
2	19.87	15.06
3	24.98	66.29
4	22.33	19.75
5	35.97	11.77
6	19.96	18.78
7	13.01	13.71
8	13.57	17.29
9	16.61	31.91
10	12.29	16.61
Avg	**22.105**	**23.879**
t-stats **P Value**	**-0.2952** **0.7719**	

We can see only the number of head rotations, provided with new data, distinguish healthy and adhd kids well.

C. 4 Motion Features from hand and foot

1. **Area under acceleration curve**

	Foot_area1	Foot_area2	Hand_area1	Hand_area2
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	30.9141551	21.97587738	49.78835997	33.7282766
4	19.2315832	13.02835069	70.35439977	47.1558199
5	71.6674915	48.84310096	97.08331014	66.1325716
6	23.8509202	16.63884425	27.74587751	18.591859
7	48.4604487	33.8142603	62.58735327	42.3175085
8	45.8590092	32.81079564	23.43666913	15.9342356
9	63.9110055	44.8647593	44.0801772	30.3703669
10	9.18140598	6.359880835	31.60892572	23.523759
11	19.7484436	12.45879275	23.74957871	16.0571041
12	21.5511722	14.96962036	34.32877798	26.5540611
13	64.9273518	47.89580579	37.47907967	26.3320846
14	9.11633445	6.582407973	27.76877602	19.3589398
15	56.3893442	38.45728622	54.31872104	37.0116521
16	10.4955039	7.389214722	16.33491861	10.8824529
17	23.357868	16.68584195	32.94015394	21.4321824
18	20.2555518	13.92278099	70.68592311	48.2271429
19	16.7302494	12.02028881	33.82878355	23.3121397

Since the first three subjects are missing data, we labeled them to be zero. Area1 and Area2 indicates the two different ways we calculated the area. The result is stored in a csv file for further statistical analysis.

2. Percentage of time over an acceleration threshold

As we increase the threshold, TAT for all subjects decrease. When we push the threshold to 5, some of the TATs get to 0. In general, subjects with ADHD have higher TATs than healthy subjects. TAT of hand and foot for the same subject may also have big differences when threshold is low.

Threshold 1:

ADHD FOOT TAT subject006: 15.974216606037398%

ADHD HAND TAT subject006: 22.27699372003511%

ADHD FOOT TAT subject010: 11.472011057360056%

ADHD HAND TAT subject010: 9.008189262966333%

ADHD FOOT TAT subject015: 0.076190476190476 2%

ADHD HAND TAT subject015: 0.6305795663879836%

ADHD FOOT TAT subject016: 14.249593642766841%

ADHD HAND TAT subject016: 8.855117995177906%

ADHD FOOT TAT subject017: 0.9009009009009009%

ADHD HAND TAT subject017: 1.9923637625824366%

ADHD FOOT TAT subject018: 3.348089032982106%

ADHD HAND TAT subject018: 1.2007095101650975%

ADHD FOOT TAT subject019: 5.459807073954984%

ADHD HAND TAT subject019: 9.733462023906748%

ADHD FOOT TAT subject020: 1.2784947533470028%

ADHD HAND TAT subject020: 3.1877790178571432%

HEALTHY FOOT TAT subject009: 5.972332256688403%

HEALTHY HAND TAT subject009: 1.6666666666666667%

HEALTHY FOOT TAT subject004: 6.727986106644368%

HEALTHY HAND TAT subject004: 6.7327602434586185%

HEALTHY FOOT TAT subject005: 4.559026182820395%

HEALTHY HAND TAT subject005: 14.658808933002481%

HEALTHY FOOT TAT subject007: 3.515137770722304%

HEALTHY HAND TAT subject007: 3.4905999281523172%

HEALTHY FOOT TAT subject008: 8.41715193223928%

HEALTHY HAND TAT subject008: 9.463227605437433%

HEALTHY FOOT TAT subject011: 1.049769654859905%

HEALTHY HAND TAT subject011: 1.0677344010677345%

HEALTHY FOOT TAT subject012: 1.0632734878856545%

HEALTHY HAND TAT subject012: 1.9311622603862326%

HEALTHY FOOT TAT subject013: 2.4566984800282783%

HEALTHY HAND TAT subject013: 1.0264285136991838%

HEALTHY FOOT TAT subject014: 11.478719228396793%

HEALTHY HAND TAT subject014: 0.2671848433325237%

Threshold 3:

ADHD FOOT TAT subject006: 6.4330844342332%

ADHD HAND TAT subject006: 6.435275845769464%

ADHD FOOT TAT subject010: 2.9774245565537893%

ADHD HAND TAT subject010: 1.565059144676979%

ADHD FOOT TAT subject015: 0.006349206349206349%

ADHD HAND TAT subject015: 0.028340654669122858%

ADHD FOOT TAT subject016: 4.000361206429474%

ADHD HAND TAT subject016: 1.4320157813984074%

ADHD FOOT TAT subject017: 0.18157692576297227%

ADHD HAND TAT subject017: 0.6178410274210343%

ADHD FOOT TAT subject018: 0.6234802668495543%

ADHD HAND TAT subject018: 0.12279983626688497%

ADHD FOOT TAT subject019: 0.8617363344051446%

ADHD HAND TAT subject019: 2.457494988492093%

ADHD FOOT TAT subject020: 0.27740923893378366%

ADHD HAND TAT subject020: 0.28599330357142855%

HEALTHY FOOT TAT subject009: 2.364556036321531%

HEALTHY HAND TAT subject009: 0.25193798449612403%

HEALTHY FOOT TAT subject004: 0.5724577088827426%

HEALTHY HAND TAT subject004: 1.6690719708853612%

HEALTHY FOOT TAT subject005: 1.004823151125402%

HEALTHY HAND TAT subject005: 3.232009925558313%

HEALTHY FOOT TAT subject007: 0.7086971311940129%

HEALTHY HAND TAT subject007: 0.6286672254819782%

HEALTHY FOOT TAT subject008: 2.929239456502559%

HEALTHY HAND TAT subject008: 2.5386313465783665%

HEALTHY FOOT TAT subject011: 0.1585982931802734%

HEALTHY HAND TAT subject011: 0.31698365031698367%

HEALTHY FOOT TAT subject012: 0.21788391145197838%

HEALTHY HAND TAT subject012: 0.22803392004560677%

HEALTHY FOOT TAT subject013: 0.7423117709437964%

HEALTHY HAND TAT subject013: 0.2990382284005496%

HEALTHY FOOT TAT subject014: 0.11215162900241125%

HEALTHY HAND TAT subject014: 0.024289531212047608%

Threshold 5:

ADHD FOOT TAT subject006: 3.5675537685876573%

ADHD HAND TAT subject006: 2.606523060301168%

ADHD FOOT TAT subject010: 1.1230131306150657%

ADHD HAND TAT subject010: 0.5884137094328178%

ADHD FOOT TAT subject015: 0.0%

ADHD HAND TAT subject015: 0.0%

ADHD FOOT TAT subject016: 1.8150623081090844%

ADHD HAND TAT subject016: 0.6064148462044275%

ADHD FOOT TAT subject017: 0.09777219079544662%

ADHD HAND TAT subject017: 0.34015966678236725%

ADHD FOOT TAT subject018: 0.03117401334247771%

ADHD HAND TAT subject018: 0.04093327875562833%

ADHD FOOT TAT subject019: 0.2958199356913183%

ADHD HAND TAT subject019: 1.1582151607394757%

ADHD FOOT TAT subject020: 0.11458207695091063%

ADHD HAND TAT subject020: 0.048828125%

HEALTHY FOOT TAT subject009: 1.0360168200377842%

HEALTHY HAND TAT subject009: 0.12273901808785528%

HEALTHY FOOT TAT subject004: 0.14793850903711325%

HEALTHY HAND TAT subject004: 0.6023718391165213%

HEALTHY FOOT TAT subject005: 0.4306384933394579%

HEALTHY HAND TAT subject005: 1.2903225806451613%

HEALTHY FOOT TAT subject007: 0.3515137770722304%

HEALTHY HAND TAT subject007: 0.14369536582445216%

HEALTHY FOOT TAT subject008: 1.052879242397506%

HEALTHY HAND TAT subject008: 1.196700360171953%

HEALTHY FOOT TAT subject011: 0.09817989577826447%

HEALTHY HAND TAT subject011: 0.016683350016683352%

HEALTHY FOOT TAT subject012: 0.07843820812271221%

HEALTHY HAND TAT subject012: 0.07126060001425212%

HEALTHY FOOT TAT subject013: 0.08837044892188052%

HEALTHY HAND TAT subject013: 0.13739594277863088%

HEALTHY FOOT TAT subject014: 0.0%

HEALTHY HAND TAT subject014: 0.008096510404015869%

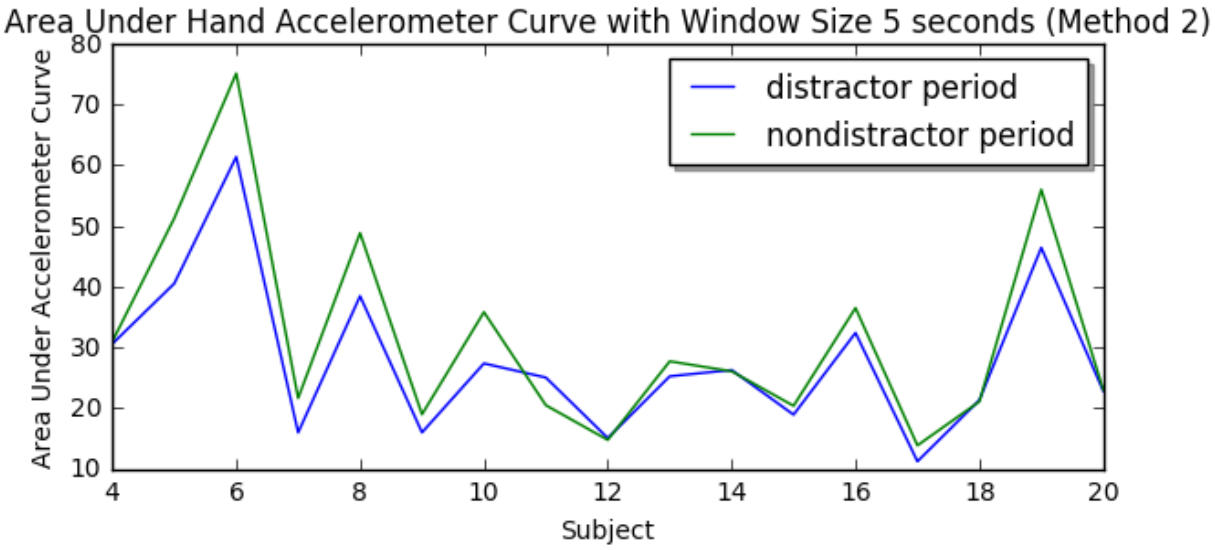
D. Event Related Analysis on Motion Data

We computed the seven features explained above:

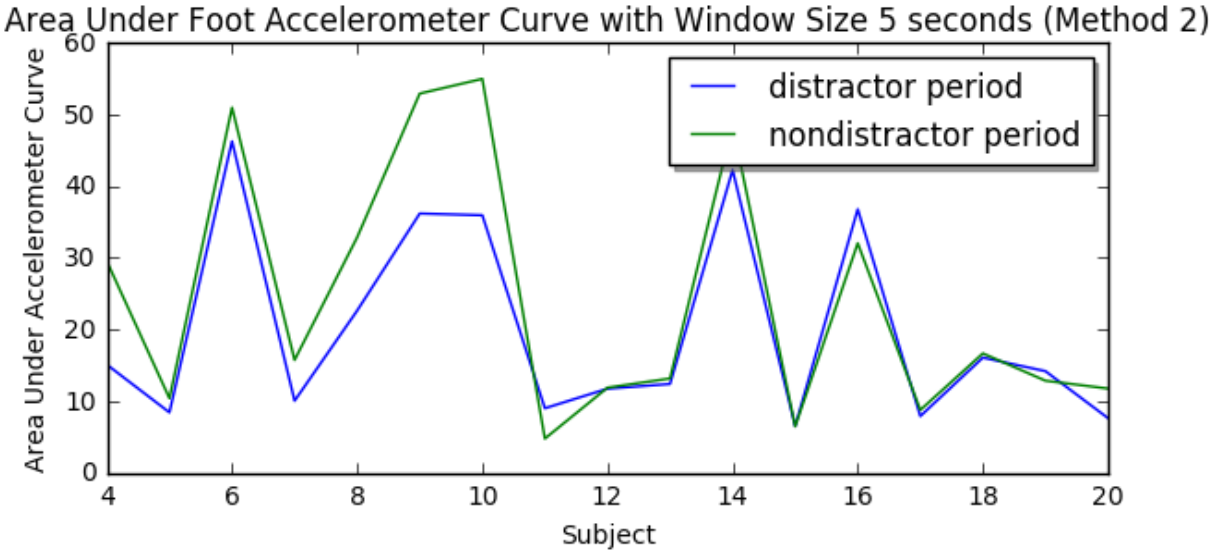
1. At the duration of the distraction
2. 5 seconds immediately before the distraction

Normalized them and compared the result.

Hand Area Under Curve (Subject 11 should be ignored due to loss of data)



Foot Area Under Curve(Subject 11 should be ignored due to loss of data)



Number of Head Rotations (NOT normalized but since distractor period is longer than pre distractor period, the conclusion is valid)

Out[28]:

HEALTHY PREDISTRACTOR HEAD ROTATIONS	HEALTHY DISTRACTOR HEAD ROTATIONS
104	52
55	25
34	22
74	14
96	42
50	12
3	0
17	0
43	10
5	1

In [29]:
```
table1
```

Out[29]:

ADHD PREDISTRACTOR HEAD ROTATIONS	ADHD DISTRACTOR HEAD ROTATIONS
71	26
21	17
180	82
70	36
83	40
90	20
28	27
48	30
75	26
70	19

```
print(avg_adhd_dis)
```

```
Avg head rotations in predistractor period for healthy kids:
48.1
Avg head rotations in distractor period for healthy kids:
17.8
Avg head rotations in predistractor period for ADHD kids:
73.6
Avg head rotations in distractor period for ADHD kids:
32.3
```

In [26]:
```
print("T-test for healthy kids:")
stats.ttest_ind(a= healthy_dis,
                b= healthy_predis,
                equal_var=False)
```

```
T-test for healthy kids:
```

Out[26]:
```
Ttest_indResult(statistic=-2.4229664214432569, pvalue=0.03036389397506789)
```

In [25]:
```
print("T-test for ADHD kids:")
stats.ttest_ind(a= adhd_dis,
                b= adhd_predis,
                equal_var=False)
```

```
T-test for ADHD kids:
```

Out[25]:
```
Ttest_indResult(statistic=-2.741009574648579, pvalue=0.017609222290404847)
```

The result uniformly shows that subjects move LESS when there IS a distraction. The t-test result for head rotation result shows there is a statistically significant difference.

III. Things to fix and to do

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1. About gravity compensation. There are several parameters in the filter that can be adjusted. But we didn't do the calibration. So although gravity are roughly compensated as shown in the graph above, there's small (small in number) error in the results, which can be the same as the actual signal. There's probably not a way to determine the EXACT linear acceleration. An alternative way is to get around gravity compensation and extract features from the raw signal, like entropy, frequency, etc.
2. Event related analysis on correct hit and omission error
3. Figure out the reason for the error (seems to be loss of data) in the standard deviation plot