Sow Monitoring Activity

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0 Presentation of the data set

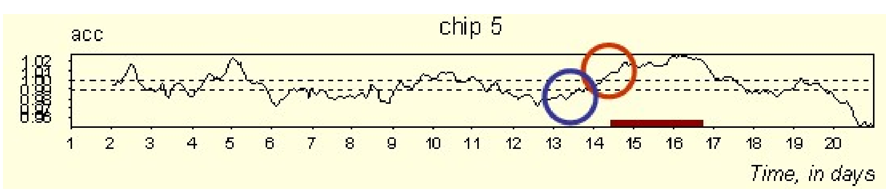
The data set originates from the recording of the body activity of four sows. Each time series represents the measure of acceleration of each sow during 20 days. The acceleration is measured in 3-dimensions (axis x, y and z), four times per second. The vector length of the acceleration regroups the three axes and is used as the main variable in the time series analysis. The percentage of missing values in the time series ranges from 35% to 45%.

During the 20 days period, three of the four sows came into oestrus. The time from the onset to the end of oestrus has been recorded.

A literature review suggests that the activity of the sows tends to increase from two days before the onset of oestrus. Therefore, it is expected to measure an increase of the acceleration around the time of oestrus, for the three sows that came into oestrus.

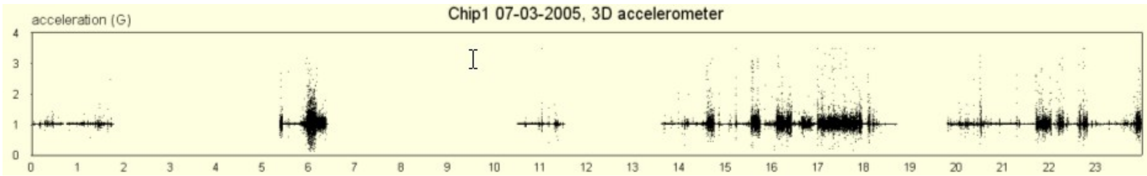
0 Structure and approach of the data set

Preliminary analysis of the data set showed that the sows' activities vary around the time of oestrus, without however presenting any clear pattern. The figure below shows the hourly moving average of one sow in the 20 days period. In the further analysis, we have tried to see if there is any connection between the acceleration data and the oestrus period (red line on the figure).



In order to be able to built a statistical model, we created a response variable for the oestrus period. The binary variable r is created to indicate when the sow is in oestrus (0: no oestrus, 1: oestrus).

The figure below presents the raw acceleration data (four measurements per second) of acceleration over a 24 hour period. We can observe that the data oscillate around the value 1. When the sow increases her velocity, we observe “positive values” – i.e. values above one. These “positive values” are followed by “negative values” – below one, which indicates a deceleration.



To quantify the total body activity (acceleration/deceleration), we transformed the acceleration data as follows: ((acc-1)^2) x 100.

0 Statistical models

Several models have been used to see if there is any relationship between the acceleration values and the oestrus period. For that, two kinds of acceleration values have been used: 1 hour average and 3 hours average.

First Model

The first model implemented is a one level model, with the acceleration as the dependent variable (acc11) and the binary response variable created for the oestrus period (r1 for sow 1) as the predictor.

This model has been implemented for three of the four sows – the sows that showed oestrus. The example below shows the model for sow 1, without random effect.

$$\mathrm{ac11}_i \sim \mathrm{N}(XB, \Omega)$$

$$\mathrm{ac11}_i = \beta_{0i}\mathrm{cons} + -0.1013(0.1460)\mathrm{r1}_i$$

$$\beta_{0i} = 0.6254(0.0557) + e_{0i}$$

$$\left[e_{0i}\right] \sim \mathrm{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[0.8929(0.0688)\right]$$

$$\textit{-2*loglikelihood(IGLS Deviance)} = 918.1998(337 \text{ of } 480 \text{ cases in use})$$

The result for this model with and without random effect is presented in annex 1. The mean of the acceleration of the four sows range from 0.63 to 1.12, which indicates a large variation of the activity between the sows. However, the effect of the binary variable (r1) is insignificant, which indicates that with this model, the oestrus period does not seem to affect the activity of the sow.

Second Model

In the second model, we kept one level (observation level), hourly average of acceleration, but we split the binary response variable into 3 responses, in order to look closer at the period just preceding the onset of oestrus:

- 0: not in oestrus,
- 1: in oestrus,
- 2: period covering two days before the onset of oestrus.

The model below has been fitted for the second sow.

$$\text{ac22}_i \sim \text{N}(XB, \Omega)$$
$$\text{ac22}_i = \beta_{0i}\text{cons} + 0.58012(0.33531)\text{r2\_1}_i + 1.11316(0.45272)\text{r2\_2}_i$$
$$\beta_{0i} = 1.04654(0.11536) + e_{0i}$$
$$\left[e_{0i}\right] \sim \text{N}(0,\ \Omega_e)\ :\ \Omega_e = \left[2.87467(0.25213)\right]$$

$$-2{*}loglikelihood(IGLS\ Deviance) = 1012.39200(260 \text{ of } 480 \text{ cases in use})$$

In this model we see that the period preceding the onset of oestrus (r2_2) has a significant positive impact on the acceleration. This means that during these two days, the sow is more active compared to the period when the sow is not in oestrus. Randomizing this model for the same sow (2) did not improve the *loglikelihood* (1010.8 compared 1012.39 without). Sow 1 and 2 did not show any significant result for the estimators. Detailed results of the model 2 analysis are presented in annex 1.

In the above model the missing values have been treated as missing data. As mentioned in the presentation of the data set, 35% to 45% of the values are missing. It would therefore be very relevant to use an imputation method. However, no correlation between the sows' activity was found, therefore imputation methods was limited.

Most of the missing data are assumed to be periods in which the sows were sleeping. For technical reasons the data transmission cut when the sow slept on the sensor measuring acceleration movements. The missing data are missing supposedly “not at random”.

In the aim of trying to improve the previous model, missing data has been given the value of 1.10e-06, which corresponds theoretically as a value of the acceleration variable when no movement is recorded – or more precisely when no change of acceleration is observed.
Besides, the next models have been also focused on seeing if there is any daily cyclic pattern for the acceleration data.

Third model

The third model that has been implemented is a multivariate response model, in which the acceleration of each sow is treated as a single variable. Here, the binary response for the oestrus period presents only two responses: heat / no heat, and the model has only one level (observation).

$$\text{resp}_{1j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{2j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{3j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{4j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{1j} = \beta_{0j}\text{cons.ac11}_{ij} + 0.04865(0.15487)\text{r1.1}_{ij}$$
$$\beta_{0j} = 0.48956(0.05212) + u_{0j}$$
$$\text{resp}_{2j} = \beta_{1j}\text{cons.ac22}_{ij} + 1.04663(0.40198)\text{r2.2}_{ij}$$
$$\beta_{1j} = 0.78388(0.11475) + u_{1j}$$
$$\text{resp}_{3j} = \beta_{2j}\text{cons.ac33}_{ij}$$
$$\beta_{2j} = 0.75737(0.04657) + u_{2j}$$
$$\text{resp}_{4j} = \beta_{3j}\text{cons.ac44}_{ij} + -0.26142(0.14733)\text{r4.4}_{ij}$$
$$\beta_{3j} = 0.60694(0.04979) + u_{3j}$$

$$\begin{bmatrix} u_{0j} \\ u_{1j} \\ u_{2j} \\ u_{3j} \end{bmatrix} \sim \text{N}(0, \Omega_u) : \Omega_u = \begin{bmatrix} 0.38598(0.04315) & & & \\ -0.01438(0.06835) & 1.93618(0.21647) & & \\ 0.03027(0.02903) & 0.04198(0.06489) & 0.34701(0.03880) & \\ 0.00380(0.02917) & 0.01616(0.06535) & 0.04539(0.02789) & 0.35276(0.03944) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 1429.25500(640 of 640 cases in use)

Randomization does not improve the model: the loglikelihood was 1392.48, against 1429.26 without randomization (for 4 df). The oestrus variable response is non significant for sow 1 and 4 (r1, r4). Sow 3 did not show oestrus so no response variable is affected. However sow 2 shows as in model 2, a significant and positive relation between oestrus period and acceleration.

In order to detect any cyclic pattern within the day, a categorical hour variable (3 hour average) is set as fixed effect.

$$\text{resp}_{1j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{2j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{3j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{4j} \sim \text{N}(XB, \Omega)$$
$$\text{resp}_{1j} = \beta_{0j}\text{cons.ac11}_{ij} + h_j$$
$$\beta_{0j} = 0.69539(0.08461) + u_{0j}$$
$$\text{resp}_{2j} = \beta_{1j}\text{cons.ac22}_{ij} + h_j$$
$$\beta_{1j} = 1.06927(0.13260) + u_{1j}$$
$$\text{resp}_{3j} = \beta_{2j}\text{cons.ac33}_{ij} + h_j$$
$$\beta_{2j} = 0.95772(0.08242) + u_{2j}$$
$$\text{resp}_{4j} = \beta_{3j}\text{cons.ac44}_{ij} + h_j$$
$$\beta_{3j} = 0.77789(0.08406) + u_{3j}$$
$$h_j = -0.07738(0.10536)\text{hour\_3.1234}_j + -0.33425(0.10536)\text{hour\_6.1234}_j + -0.33454(0.10536)\text{hour\_9.1234}_j + -0.33915(0.10536)\text{hour\_12.1234}_j + -0.30051(0.10536)\text{hour\_15.1234}_j + -0.17109(0.10536)\text{hour\_18.1234}_j + -0.04590(0.10536)\text{hour\_21.1234}_j$$

$$\begin{bmatrix} u_{0j} \\ u_{1j} \\ u_{2j} \\ u_{3j} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} 0.36852(0.04120) & & & \\ -0.03153(0.06853) & 2.03613(0.22764) & & \\ 0.00287(0.02672) & 0.03492(0.06285) & 0.30983(0.03464) & \\ -0.00636(0.02854) & -0.02249(0.06710) & 0.01979(0.02621) & 0.35353(0.03952) \end{bmatrix}$$

*-2*loglikelihood(IGLS Deviance)* = 1415.13900(640 of 640 cases in use)

On the total period, which includes presence of oestrus for three of the four sows, we can see that only hour 12 (period 12-15) and hour 15 (period 15-18) present similarities between days. This means that the sows have the same activity level at this time of the day. The other these 3 hours average periods are not significant.

Fourth model

Here is presented an alternative model, in which the oestrus response (r) is set as the dependant variable, and the acceleration as predictor. The model below presents the calculation made for sow 1.

$$r1_{ij} \sim \text{Binomial}(\text{cons}_{ij}, \pi_{ij})$$
$$\text{logit}(\pi_{ij}) = \beta_{0j}\text{cons} + -0.147(0.212)\text{ac11}_j$$
$$\beta_{0j} = -1.687(0.192) + u_{0j}$$

$$\left[u_{0j}\right] \sim N(0,\ \Omega_u)\ :\ \Omega_u = \left[0.006(0.619)\right]$$

$$\text{var}(r1_{ij}|\pi_{ij}) = \pi_{ij}(1 - \pi_{ij})/\text{cons}_{ij}$$

The probability of the expected response is 0.15617 (ALogit(-1.687)). The value of the odd ratio of the acceleration is positive (0.863) but non significant. This indicates that during the oestrus period, the acceleration of sow 1 tends to decrease – but not significantly.

At last, we attempted to see the presence of any cyclic pattern during the whole period preceding the start of the first oestrus (first 10 days). A two-level model with observation nested within the hours has been implemented but the results failed to show any cyclic pattern.

0 Discussion and conclusion

As the light of the above models, we can see that our data set does not fit these kinds of models. The structure of the data does not make it possible to easily fit hierarchical models. Difficulties also arose from the fact that there exists a large number of missing values. The data used in the models were either hourly average or 3 hours averages, from raw data measured four times per second. This implies a lot of information loss.

The results showed a substantial variation of mean activity among sows as well as different reactions (increase or decrease of activity) during the oestrus period, compared to non oestrus period. The attempt to look for any kind of cyclic component failed by using these models.

Annex 1

Model 1

	Beta 0	*se*	Beta 1	*se*	Var	*se*	Var	*se*	Cov	*se*	LogLik	LogLikR
1	0.6254	*0.0557*	-0.1013	*0.1460*	0.8929	*0.0688*	1.0154	*0.0846*	-0.4213	*0.046*	918.1998	874.7574
2	1.1188	*0.1128*	0.5078	*0.3379*	2.9415	*0.258*	3.045	*0.2833*	-0.464	*0.312*	1018.369	1016.819
3	0.813	*0.037*			0.532	*0.039*					838.412	
4	0.6523	*0.0398*	-0.1674	*0.1655*	0.5421	*0.0402*	0.5638	*0.0431*	-0.1882	*0.036*	807.8611	799.0374

Beta0: constant mean

Beta1: response binary variable mean

Model 2

	Beta 0	*se*	Beta 1	*se*	Beta 2	*se*	Var	Loglik	LoglikR
1	0.61234	*0.0594*	-0.08819	*0.1474*	0.1077	*0.1703*	0.89187	917.8001	859.1467
2	1.04654	*0.1154*	0.58012	*0.3353*	1.11316	*0.4527*	2.87467	1012.392	1010.802
3	0.81348	*0.0374*						838.4121	
4	0.01009	*0.0019*	-3.0071	*2.632*	-2.31399	*1.822*	0.00113	2213.345	788.3103

Beta0: constant mean

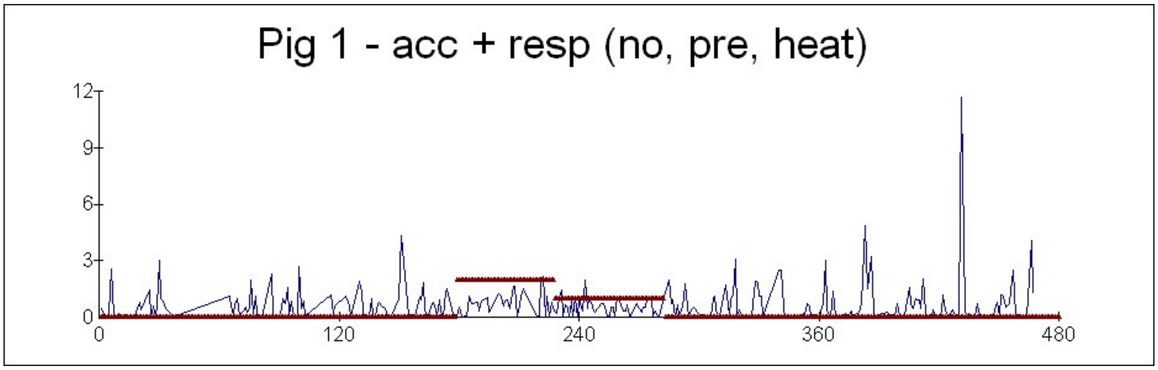
Beta1: response binary variable. Value of 1, presence of oestrus.

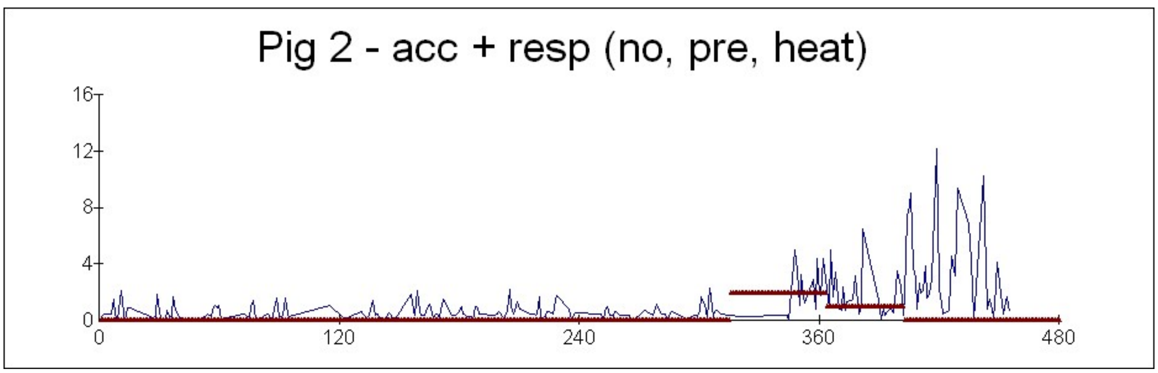
Beta2: response binary variable. Value of 2, 2 days before oestrus.

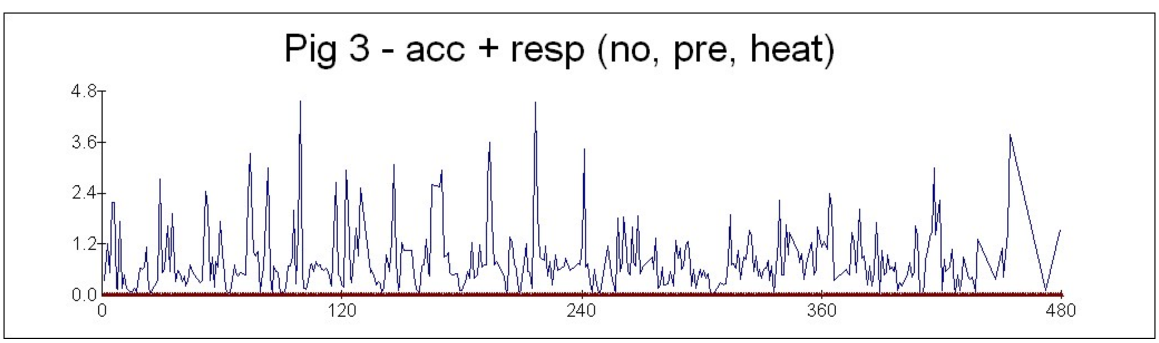
The Wald test for sow 1 in model 2 showed that only the constant part is significant, while the oestrus period does not seem to affect the acceleration of the sow.

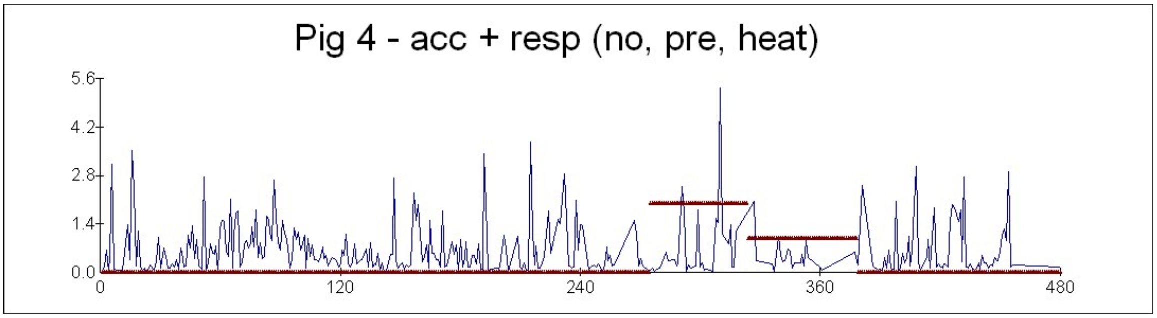
Annex 2

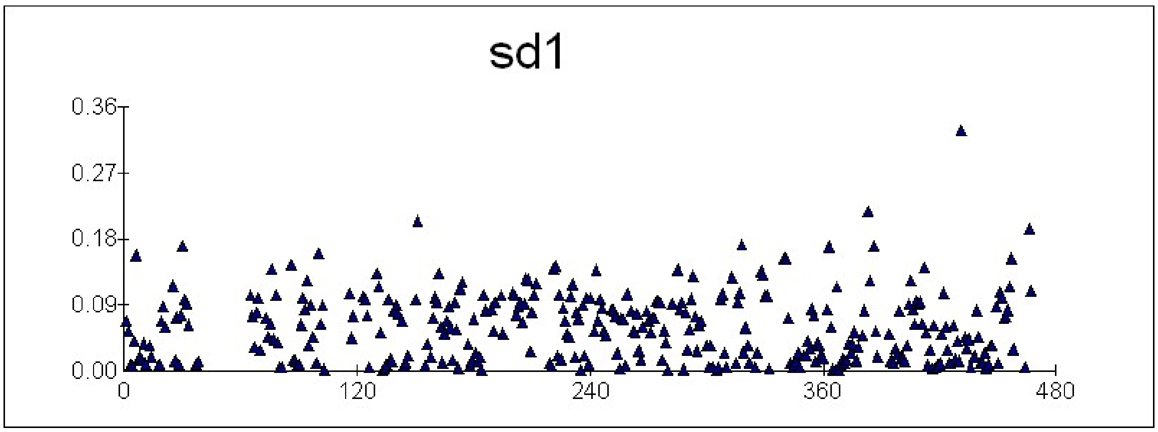
Basic statistic and graphics








Pig 4 - acc + resp (no, pre, heat)
5.6
4.2
2.8
1.4
0.0
0
120
240
360
480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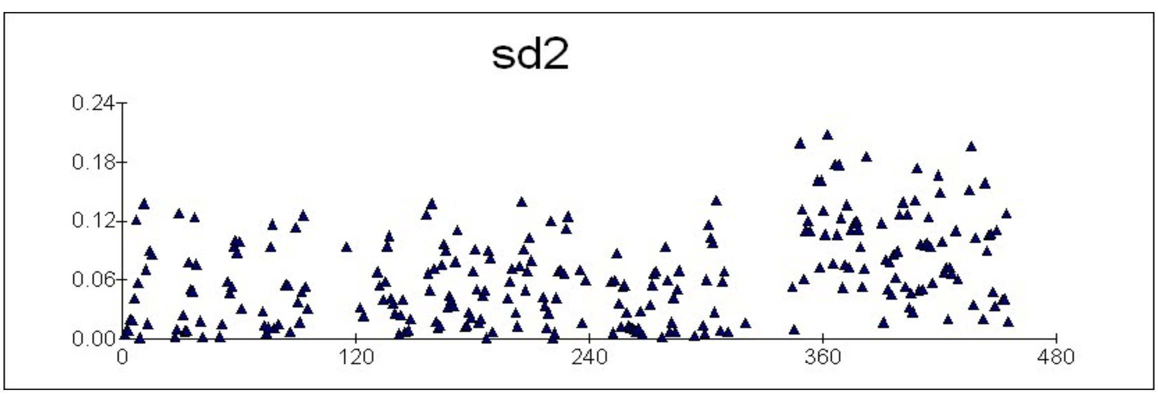
0.27
0.18
0.09
0.00
0
120
240
360
480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0.12
0.06
0.00
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360
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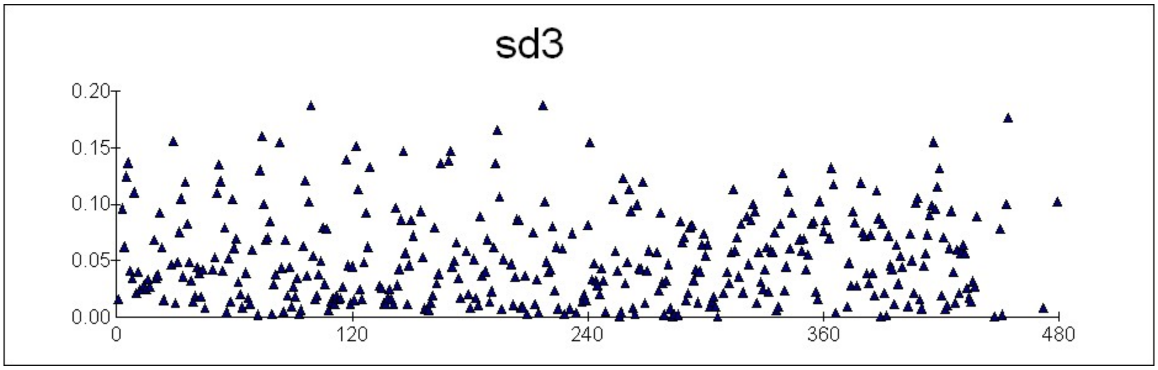
sd3
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0.10
0.05
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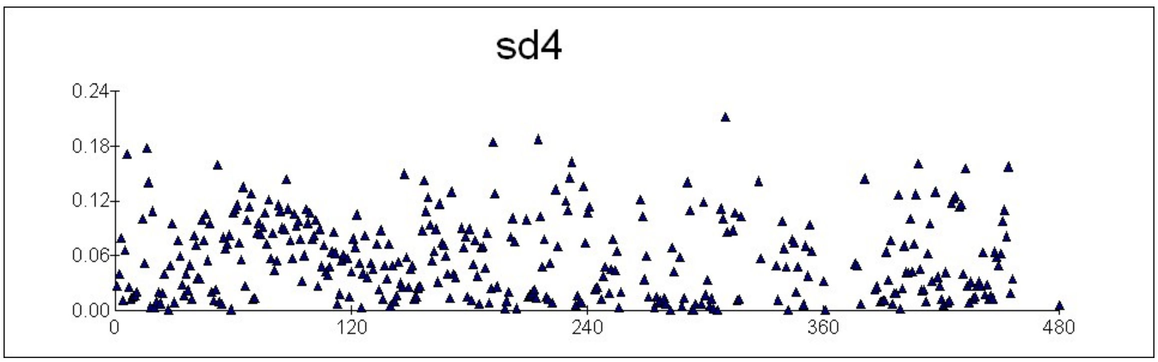
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0.12
0.06
0.00
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120
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