Changes in eating time in dairy cows during the transition period

Author:
Esther Piersma BSc
Utrecht University

Supervisors:
Peter Hut DVM MSc
Frank van Eerdenburg, DVM, PhD, Dipl ECBHM
Utrecht University
Faculty of Veterinary Medicine; Department of Farm Animal Health

Abstract

The number of cows on farms is increasing and less time is available to monitor cattle individually around the time of calving. The aim of this study was to investigate if it is possible to predict approaching parturition in cows based on their eating pattern as determined with a sensor, the Nedap Smarttag Neck. Furthermore, postpartum the difference in the eating/licking behaviour between heifers and older cows and influence of time of parturition on licking behaviour were investigated. The final objective was to determine if feeding time, as recorded with the Nedap Smarttag Neck, can be used to demonstrate that the calf is born.

Mean time eating showed a circadian rhythm. A decline in time spent eating was observed from ten days antepartum and an even stronger decline was seen in the last four days before calving. A striking increase in time spent eating is registered in the first two hours post partum. The peak in time spent 'eating' is actually the licking of the calf. There was no difference in licking/eating behaviour between heifers and multiparous cows and there was no difference in licking/ eating behaviour between groups cows classified on time of calving.

Mean time eating per two hours could be used as one of the parameters to predict the time of parturition or to demonstrate that the calf is born, but for a reliable attention, more behavioural parameters need to be combined. Lying behaviour and ruminating activity could be a good addition. So electronic data loggers that register time spent feeding could be useful tools to assist management in the periparturient period but further study is necessary.

Keywords

Transition period; dairy cows; eating behaviour; parturition.

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Abbreviation key:

PS = parturition score**; PRBT=** progesterone rapid blood test**; DMI =** dry matter intake.

1. Introduction

Dairy cattle need to be monitored individually around the time of calving. In this way the farmer can estimate the time of parturition and management steps can be taken to optimize the calving process (Jensen 2012). Possible problems around parturition can be detected as soon as possible and unnecessary pain and distress can be minimized. (Miedema, Cockram et al. 2011b). In Europe, the number of cows on farms is increasing so stockmen are responsible for larger herds (Raussi 2003). This implies that there is less time to individually monitor the cattle (Raussi 2003).

Behaviour of cattle changes prior to parturition (Maltz, Antler 2007, Huzzey, Von Keyserlingk et al. 2005). Parturition is divided into three stages (Noakes, Parkinson et al. 2001, Jackson 2004). The first stage starts with dilatation of the soft tissues of the birth canal, including cervix, vulva and ligaments of the pelvis (Noakes, Parkinson et al. 2001, Jackson 2004, Schuenemann 2012). Signs of imminent calving are distention of the perineum and vulva region, enlargement of the mammary gland and secretion of vaginal mucous (Schuenemann 2012).Variation exists in behavioural signs between cows and heifers in the periparturient period (Schuenemann 2012). The first stage ends with full dilatation of the cervix and appearance of the amniotic sac outside the vulva (Schuenemann 2012). The second stage ends when the fetus is expelled and the third stage ends when the placenta is expelled (Noakes, Parkinson et al. 2001, Jackson 2004). The stages are characterised by, behavioural, hormonal and physical changes (Titler, Maquivar et al. 2015). Under normal conditions, the stages merge with each other and become a continuous process (Noakes, Parkinson et al. 2001, Jackson 2004). Changes in behaviour can provide information in the progress of parturition.

A decline in dry matter intake (DMI) is seen during the final two to three weeks before calving (Grummer, Mashek et al. 2004, Huzzey, Veira et al. 2007). DMI declines a little bit more for cows than for heifers (Huzzey, Veira et al. 2007) According to (Schirmann, Chapinal et al. 2013) cows spent less time feeding twenty-four hours before calving, compared with baseline.
Automated systems are increasingly used for feeding and milking in dairy cattle and also oestrus can be detected with a sensor (Miedema, Cockram et al. 2011b). New technology is being developed to monitor health (Miedema, Cockram et al. 2011b). One of the most suitable events, with health risks, for routine monitoring is parturition (Mottram 1997). So using sensors, that monitor behavioural parameters before calving could be useful tools to predict parturition.

The first aim of this study was to determine if there is a pattern for the time spent eating, forty days antepartum till time of parturition. This to get a clear picture of the changes in time spent eating per day, for a large herd, in this period. For this purpose automatically generated data on feeding time per two hours is used.

A second goal was to use data on time spent feeding per two hours to determine if it is possible to indicate/predict, as accurate as possible, the moment of parturition for cows. If this is possible, available data on time spent eating could be used to predict parturitions in the future.

Another point of attention was the time immediately after calving. The cow's first priority after parturition is the calf. Immediately after calving, licking the calf is the predominant behaviour shown by cattle (Edwards, Broom 1982). The first hour postpartum licking occupied 30% to 50% of the time (Edwards, Broom 1982). Most cows start licking their calf within five minutes of calving (Illmann, Špinka 1993). With time after calving a decrease of licking is seen with a large drop of 50% from the first to the second hour postpartum (Edwards, Broom 1982). The third goal of this study was to determine if the eating sensor can be used to demonstrate that the calf is born, by determining a pattern in time spent feeding postpartum. Data on time spent eating per two hours will be used.

The fourth aim of this study was to determine if there is a difference between heifers and older cows in the licking behaviour after parturition. Data on licking behaviour could possibly help to show that the calf is born. During the transition period, heifers and older cows, showed differences in feeding behaviour, exploratory behaviour at the feedbunk, social behaviour and also lying behaviour (Neave, Lomb et al. 2017). Some differences in behaviour between heifers and older cows must be a

consequence of the experience of the cow during previous parturitions (Edwards, Broom 1982). If it is clear if there are differences in licking behaviour between heifers and older cows than this could be taken into account. Time spent feeding, two hours postpartum will be analyzed for heifers and multiparous cows.

A fifth goal of this study was to determine if time of parturition influences licking behaviour. Several studies have reported a less active feeding period at night and an active feeding period during the day (DeVries, von Keyserlingk et al. 2003, DeVries, von Keyserlingk 2005). This day and night rhythm could have an influence on the licking behaviour of cattle. Data on licking behaviour could possibly help to show that the calf is born. If it is clear there are differences in licking behaviour depending on time of parturition than this could be taken into account. For this final aim, data on time spent feeding per two hours was used. The difference in feeding time, two hours postpartum will be analyzed for time of parturition.

2. Materials and Methods

2.1 Nedap-Vetvice-WUR-UU project

The data used in this field study is part of a large project set up by Nedap, Vetvice, Wageningen University and Research and Utrecht University. In this extensive study cattle are monitored in the transition period. Nedap is a technology company that provided electronic data loggers to dairy farms in this project. Vetvice is a veterinary concultancy company that delivered information on husbandry to dairy farmers. Wageningen University and Research is an university and research centre in the Netherlands that focusses specifically on three key areas; “food and food production”, “habitat and health”and “lifestyle and living conditions”. Utrecht University offers education and research of the highest quality.

2.2 Housing and animals

Data is collected at 18 dairy farms, in the Netherlands, from six weeks prepartum to four weeks postpartum. Data collection started April 2014 and data is still collected. The freestall barns with slatted floors can be considered representative for the Dutch dairy farming, with an average of 150 dairy cows per farm. Nine farms used conventional milking parlors, the other nine automatic milking systems. Both groups contain farms using rubber mattresses in the cubicles and farms using deep bedding systems. All dairy farms used straw bedded calving pens. During the dry period, the cows received an adequate total mixed ration and water. Milking cows were dried off about six weeks before estimated parturition.

2.3 Management in transition period

Farmers were asked to administrate time of parturition, calving type, calving signals and time of expulsion of the placenta, diseases and other abnormalities. All collected cow specific data about the periparturient period was entered in Excel.

2.4 Electronic data loggers

All data from the electronic data loggers were visible in Velos®, a computer program designed by Nedap. Velos® was linked to the farm management program so information about age, lactation and reproduction status could be viewed. The data in Velos® can be viewed in two hour blocks. Feeding data is presented by the Nedap Smarttag Neck in seconds per 15 min so eight periods of 15 minutes had to be combined to be able to use feeding time per two hours. To acquire the

eating time per six hours, twelve hours or a day, respectively, 24, 48 and 96 periods of a quarter of an hour have to be summed. The moment of calving (expulsion of the calf) is the moment zero.

2.4.1 Feeding data

Feeding time was recorded with the Nedap Smarttag Neck. This sensor is attached to the collar. The eating-measurement is based on the specific head movements of the cow during the intake of roughage and fresh grass. The head of the cow makes short, powerful movements, during intake of roughage in the free stall barn and/or in the pasture. The algorithm does not distinguish between eating at the feed fence and grazing, both behaviours are classified as feeding. While eating, the specific head movements are recognized by the algorithm. During the feeding period the cow's head is regularly raised to a horizontal position to grind the roughage that was taken in and to swallow it. Then the head is directed down again and another portion roughage or fresh grass is taken in. All these activities of the cow are classified by the algorithm as eating. Very short resting or ruminating periods, seconds to a minute, are counted in the total eating time. The adjusted algorithm determines the duration of the feeding time. As measure of movement, acceleration is used by the Nedap Smarttag Neck. The x-, y- and z-axis are used to determine the angle to the floor so head positioning can be determined. Using movement and position of the head, feeding time can be determined. The pattern that is seen as active feeding behaviour shows: head downwards, head upwards (short distance), chewing and head downwards. The data was stored in seconds per 15 minutes and saved for 24 hours, so data from the sensor had to be read out at least once a day. During this study "real life" parturition was compared with the registered time spent feeding, it was concluded, that licking of the calf is recorded by the data logger as time spent eating.

2.5 Data collection

Data was collected from each cow in the transition period from 42 days prepartum to 28 days postpartum. For this field study, data was used from forty days prepartum up to and including four days postpartum. In the original database data was available of 3375 cows. Cattle with missing or inconsistent data were excluded from this study, also the time of calving had to be known. Caesareans, still births and twins were excluded. Cattle experiencing unassisted and assisted births were included in the study. Information about lactation number was needed to distinguish between heifers and cows in the period before and after calving. For all available data time of birth is considered moment zero.

After data refinement 527 cows (mean parity = 3.06, range 1 to 10) were included for the first goal of the study, finding a pattern in time spent feeding . For the first goal time, forty days antepartum till time of parturition, was divided in three periods of ten days and eleven periods of one day. Day -40 up to day -30, day -30 up to day -20, day -20 up to day -10, day -10, -9, -8, -7, -6, -5, -4, -3, -2, -1 and 0. Use was made of feeding time per day.

For the second, third, fourth and fifth goal, 969 cows (mean parity = 2.95, range 1 to 12) were included after data refinement. Because data, used for the second, third, fourth and fifth goal, was derived from a smaller period than the first goal, less data was missing and more cattle, 442 cows, remained in this study.

For the second goal, feeding time three days antepartum is divided in six periods of twelve hours and twelve periods of six hours. Feeding time two days antepartum is divided in twenty-four periods of two hours. Finally, feeding time ten days antepartum till four days postpartum is divided in sixty periods of six hours. For the third goal, the change in time spent feeding two hours postpartum relative to the period eight day till six days antepartum was analyzed. For the fourth goal, the difference between heifer and cows in time spent eating during the first two hours postpartum was analyzed. For the final goal cattle were divided in groups on the basis of time of parturition and time spent eating during the first two hours postpartum was analyzed.

2.6 Data presentation and statistical analysis

Data is provided by Nedap livestock management and for data refinement Microsoft Excel was used. Statistical analysis is performed using R-studio as explained in section 2.6.1 and section 2.6.2. The 15-min. period in which calving took place was defined as period zero. Time, in this study, was indicated in days and hours. Two days and twelve hours antepartum is presented as -2;12:00. Two hours after calving is presented as +0;02:00.

2.6.1 Eating behaviour before parturition

To analyze the difference in mean time eating per day, before parturition, Linear Mixed-Effects Model in R-studio is used. With time as a fixed effect and cow as a random effect.

To study the period forty day prepartum up to and including time of calving, time before parturition is divided in 14 periods. Day -40 up to day -30(-40), day -30 up to day -20 (-30), day -20 up to day -10 (-20), day -10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0. Each period is compared with period -40.

To investigate the 72 hours before calving, this period is divided in six periods of twelve hours. Each period is compared to the first twelve hours of this 72 hour period. This means that every period is compared to the period 72 - 6o hours antepartum. The 72 hours prepartum are also divided in twelve periods of six hours. Each period is compared to the first six hours of this 72 hour period. This means that every period is compared to the period 72 - 66 hours antepartum. To analyze the last two days before calving, the 48 hours are divided in 24 periods of two hours. Each period is compared to the first two hours of this 48 hour period. This means that every period is compared to the period 48 - 46 hours antepartum. Finally, ten days antepartum up to and including four days postpartum are divided in sixty periods of six hours. Each period is compared to the first six hours of this 60 hour period. This means that every period is compared to the period 60 - 54 hours antepartum.

2.6.2 Eating behaviour postpartum

To investigate mean time eating two hours postpartum, between groups classified on the basis of time of calving, analysis of variance (ANOVA) in R-studio is used. Analysis of variance(ANOVA) was also used to analyze the difference between cows and heifers in the different groups in the two hours postpartum. The increase in mean time eating , two hours postpartum, was also analyzed using a two factor ANOVA with interaction. Residuals were checked using a normal probability plot.

3. Results

3.1 Eating behaviour before parturition

The eating time registered by the Nedap Smarttag Neck, in the period 40 days prior to parturition to the moment of giving birth, showed a circadian rhythm (Figure 1.). Results were obtained from 527 cows. The moving average was represented by line y = -0.2567x + 1830.7. So a small decline in the mean time eating per two hours was seen in this period of 40 days antepartum.

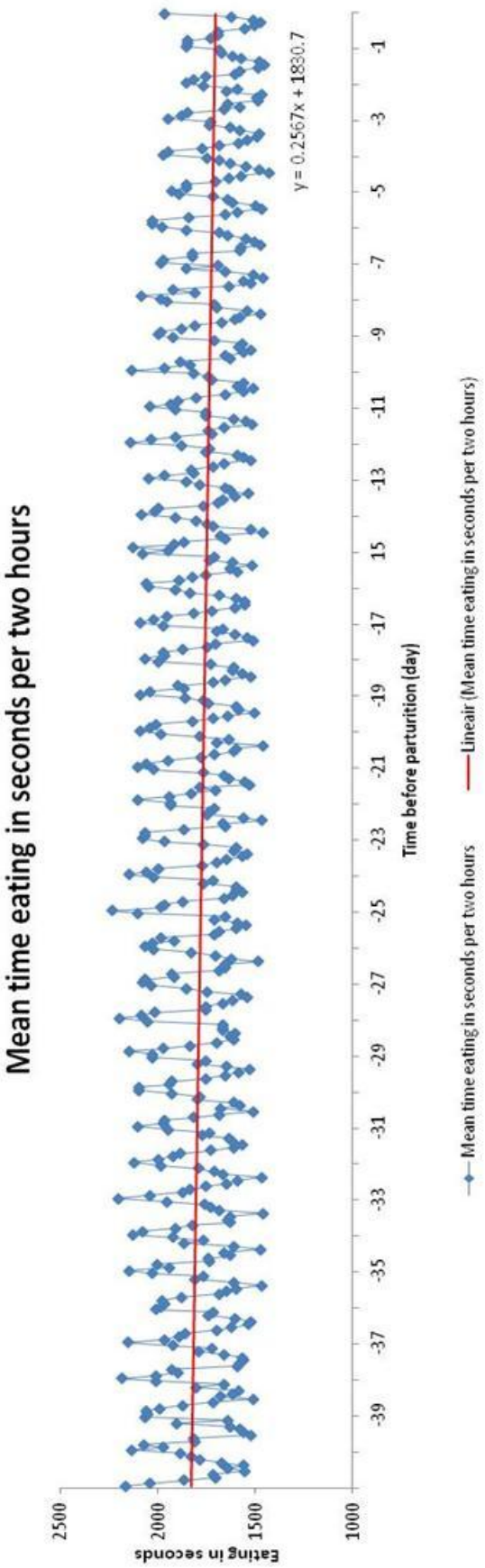

Figure 1. Mean time eating per two hours in the period 40 days prior to parturition up to and including the moment of calving.

The period of forty days antepartum, was divided in fourteen periods. Three periods of ten days and eleven periods of one day. Day 40 till day 30 antepartum (period -40), day 30 till day 20 antepartum (period -30), day 20 till day ten antepartum (period -20), day ten antepartum (period -10) , day nine antepartum (period -9), and so on. Data was analyzed using Linear Mixed-Effects Model in R-studio (Table 1.). Each period was compared with the mean time eating per day in period 40 days antepartum till 30 days prior to calving. Differences compared to this period in mean time eating per day are presented in table 1.Mean time eating per day in period -30 till period -20 was fairly constant relative to period -40. In subsequent periods a decrease in feeding time per day was seen.

By dividing the mean time eating per day by the standard error, the t-value (standardized estimate) is obtained. Looking at the standardized estimate of mean time eating per day, the 14 periods (mean time eating) could be divided in three parts. Part one runs from period -40 up to period -10. Part two runs from period -10 till period -4 and part 3 runs from period -4 till moment of parturition.

Table 1. Forty days antepartum up to and including moment of parturition divided in 14 periods. Df = 6838 and t-value = standardized estimate. Mean time eating per day is divided by the standard error to obtain the standardized estimate.

Period (day)	Mean time eating per day	Std. Error	t-value	p-value
-40 till -30	21502.98	257.36	83.55	0.00
-30 till -20	104.83	207.03	0.50	0.61
-20 till -10	-164.45	207.03	-0.79	0.43
-10	-667.08	207.03	-3.22	0.00
-9	-515.77	207.03	-2.49	0.01
-8	-579.58	207.03	-2.80	0.01
-7	-789.10	207.03	-3.81	0.00
-6	-1022.91	207.03	-4.94	0.00
-5	-537.15	207.03	-2.59	0.01
-4	-1417.80	207.03	-6.85	0.00
-3	-1329.89	207.03	-6.42	0.00
-2	-1488.15	207.03	-7.19	0.00
-1	-1910.57	207.03	-9.23	0.00
0	-1196.48	207.03	-5.78	0.00

The periods are classified on the basis of standardized estimate in table 1. In figure 2 standardized estimates are plotted against time. A two step decrease in standardized estimates before parturition was visible. Standardized estimates showed a decline at ten days antepartum and an even stronger decline in standardized estimates is seen at four days antepartum. This means there was a decline in mean time eating per day at day ten relative to period 40 days antepartum till 30 days prior to calving and an even stronger decline in mean time eating per day at day four antepartum relative to period 40 days antepartum till 30 days prior to calving.

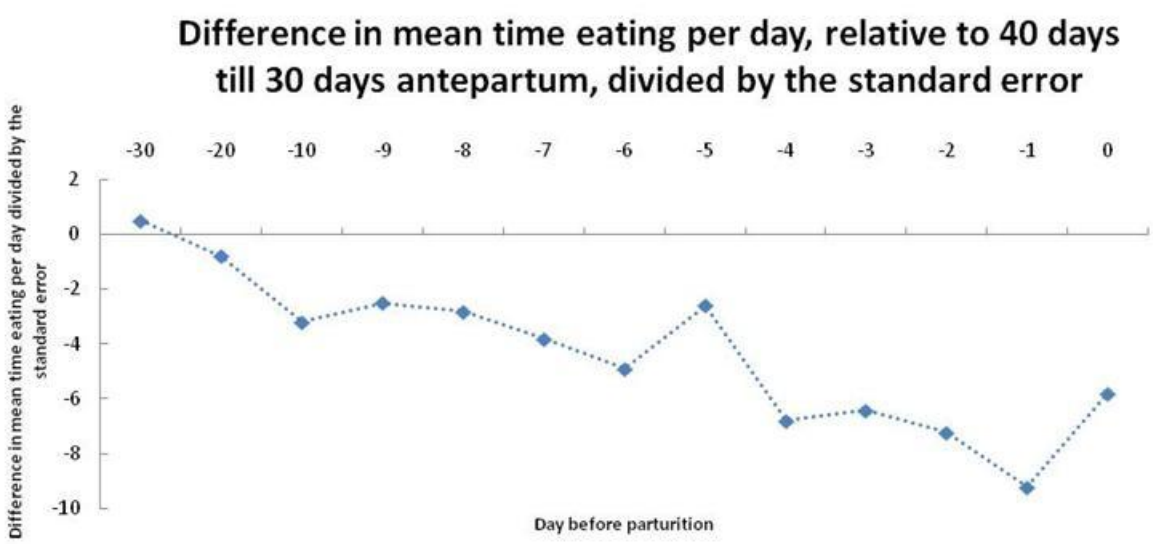

Figure 2. The standardized estimates of thirteen of the fourteen periods in the period; 40 days antepartum up to and including moment of calving. To obtain the standardized estimate, the difference in mean time eating per day, relative to 40 till 30 days prior to calving, was divided by the standard error. The first period, 40 days antepartum till 30 days prior to calving was not displayed in the figure.

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Compared to the moving average in figure 1, forty days antepartum, a stronger decline in the moving average in figure 3, ten days prior to calving was seen. This decrease is defined by the line: $y = -0.887x + 1796.4$. Results were obtained from 969 cows and mean time per two hours is used.

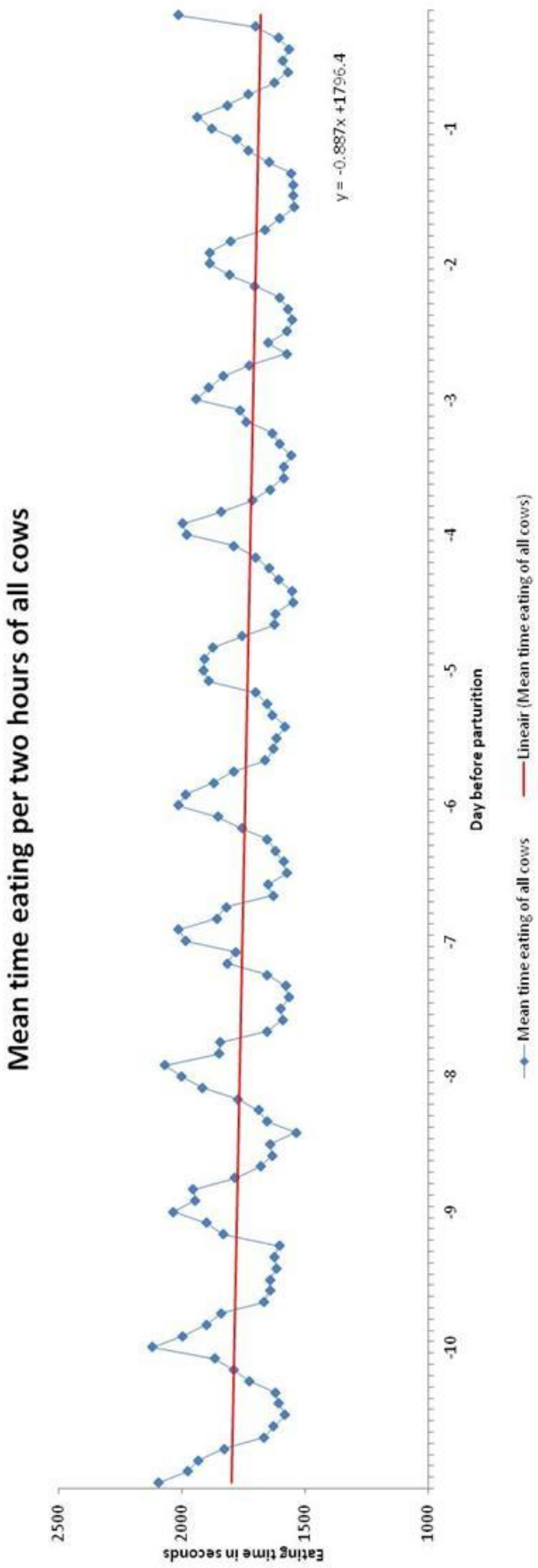

Figure 3. Mean time eating per two hours from ten days till parturition.

The last 72 hours before parturition were divided in six periods of 12 hours and the circadian rhythm is visible again (Figure 4). The daily eating routine of all 969 cows used in this study is shown. Each period was compared with period 72 hours antepartum till 60 hours antepartum (period -3;00:00 till -2;12:00 in table 2). In all the successive periods a decline in mean feeding time was observed except for the period 24 hours antepartum –till 12 hours antepartum (p-value = 0.61). Here an small increase in feeding time was seen.

Table 2. Last 72 hours before calving divided in six periods of twelve hours. Df = 2630 and t-value = standardized estimate. The standardized estimate is obtained by dividing the difference in mean time eating per day, relative to -3;00:00 till -2;12:00 prior to calving, by the standard error.

Period (day;hour)	Mean time eating per twelve hours	Std. Error	t-value	p-value
-3;00:00 till -2;12:00	10558.78	184.92	57.10	0.00
-2;12:00 till -2;00:00	-1102.73	205.71	-5.36	0.00
-2;00:00 till -1;12:00	-459.54	205.71	-2.23	0.03
-1;12:00 till -1;00:00	-1065.61	205.71	-5.18	0.00
-1;00:00 till -0;12:00	104.74	205.71	0.51	0.61
-0;12:00 till -0;00:00	-915.80	205.71	-4.45	0.00

Groups are classified on the basis of standardized estimate in figure 4.

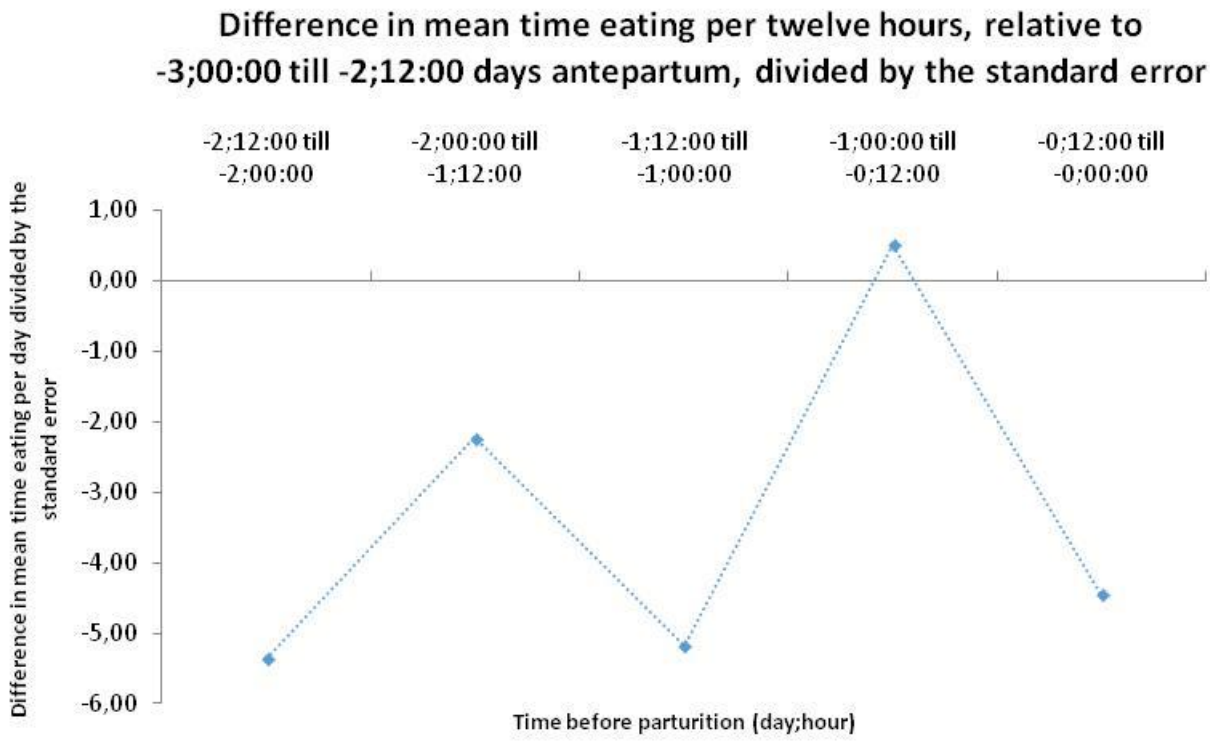

Figure 4. The standardized estimates of five of the six periods of twelve hours in the period; three days antepartum up to and including moment of parturition. To obtain the standardized estimate, the difference in mean time eating per day, relative to period -3;00:00 till -2;12:00 prior to calving, was divided by the standard error. The first period, -3;00:00 till -2;12:00 was not displayed in the figure.

The last 72 hours before giving birth were divided in 12 periods of six hours. Each period was compared with the period 72 hours prior to calving till 66 hours antepartum (period -3;00:00 till -2;18:00 in table 3).

Table 3. Last 72 hours before calving divided in twelve periods of six hours. Df = 5786 and t-value = standardized estimate. Mean time eating per day is divided by the standard error to obtain the standardized estimate.

Period (day;hour)	Mean time eating per six hours	Std. Error	t-value	p-value
-3;00:00 till -2;18:00	5675.77	115.70	49.06	0.00
-2;18:00 till -2;12:00	-792.75	142.04	-5.58	0.00
-2;12:00 till -2;06:00	-1227.07	142.04	-8.64	0.00
-2;06:00 till -2;00:00	-668.40	142.04	-4.71	0.00
-2;00:00 till -1;18:00	-243.65	142.04	-1.72	0.09
-1;18:00 till -1;12:00	-1008.64	142.04	-7.10	0.00
-1;12:00 till -1;06:00	-1160.36	142.04	-8.17	0.00
-1;06:00 till -1;00:00	-698.00	142.04	-4.91	0.00
-1;00:00 till -0;18:00	-121.98	142.04	-0.86	0.39
-0;18:00 till -0;12:00	-566.03	142.04	-3.99	0.00
-0;12:00 till -0;06:00	-1140.27	142.04	-8.03	0.00
-0;06;00 till -0;00:00	-570.51	142.04	-4.02	0.00

Groups were classified on the basis of standardized estimate in figure 5. The circadian rhythm of 969 cows is visible. The standardized estimate at time -0;00:00 is less negative than at time -0;06:00, indicating an increase in the mean time eating in the last six hours antepartum.

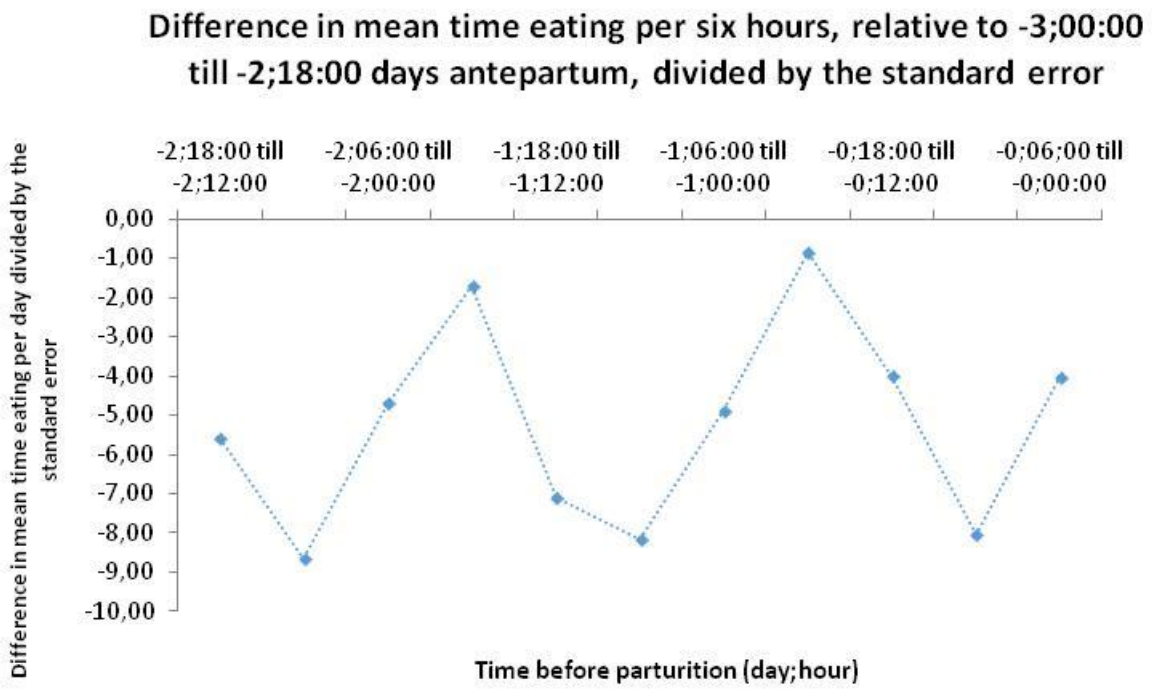

Figure 5. The standardized estimates of eleven of the twelve periods of six hours in the period; three days antepartum up to and including moment of parturition. To obtain the standardized estimate, the difference in mean time eating per day, relative to period -3;00:00 till -2;18:00 prior to calving, was divided by the standard error. The first period, -3;00:00 till -2;18:00 was not displayed in the figure.

Then the last 48 hours before parturition were divided in 24 periods of two hours. Each period was compared to 48 hours antepartum till 46 hours prior to parturition (period -2;00:00 till -1;22:00 in table 4.)

Table 4. Last 48 hours before parturition divided in twenty-four periods of two hours. Df = 12098 and t-value = standardized estimate.

Period (day;hour)	Mean time eating per two hours	Std. Error	t-value	p-value
-2;00:00 till -1;22:00	1857.66	55.61	33.41	0.00
-1;22:00 till -1;20:00	-38.12	73.28	-0.52	0.60
-1;20:00 till -1;18:00	-102.75	73.28	-1.40	0.16
-1;18:00 till -1;16:00	-255.05	73.28	-3.48	0.00
-1;16:00 till -1;14:00	-278.24	73.28	-3.80	0.00
-1;14:00 till -1;12:00	-372.57	73.28	-5.08	0.00
-1;12:00 till -1;10:00	-399.83	73.28	-5.46	0.00
-1;10:00 till -1;08:00	-375.61	73.28	-5.13	0.00
-1;08:00 till -1;06:00	-282.13	73.28	-3.85	0.00
-1;06:00 till -1;04:00	-236.61	73.28	-3.23	0.00
-1;04:00 till -1;02:00	-184.76	73.28	-2.52	0.01
-1;02:00 till -1;00:00	-173.85	73.28	-2.37	0.02
-1;00:00 till -0;22:00	0.52	73.28	0.01	0.99
-0;22:00 till -0;20:00	-10.16	73.28	-0.14	0.89
-0;20:00 till -0;18:00	-9.55	73.28	-0.13	0.90
-0;18:00 till -0;16:00	-129.48	73.28	-1.77	0.08
-0;16:00 till -0;14:00	-166.89	73.28	-2.28	0.02
-0;14:00 till -0;12:00	-166.89	73.28	-2.28	0.02
-0;12:00 till -0;10:00	-299.45	73.28	-4.09	0.00
-0;10:00 till -0;08:00	-352.78	73.28	-4.81	0.00
-0;08:00 till -0;06:00	-385.25	73.28	-5.26	0.00
-0;06:00 till -0;04:00	-343.58	73.28	-4.69	0.00
-0;04:00 till -0;02:00	-230.56	73.28	-3.15	0.00
-0;02:00 till -0;00:00	108.65	73.28	1.48	0.14

Groups were classified on the basis of standardized estimate in figure 6. A more accurate representation of the mean time eating became visible. The slope of the line is the steepest in the last two hours antepartum. The increase in the mean time eating, in the last six hours antepartum, visible in figure 5 appears to be caused by the increase of the mean time eating in the last two hours before parturition.

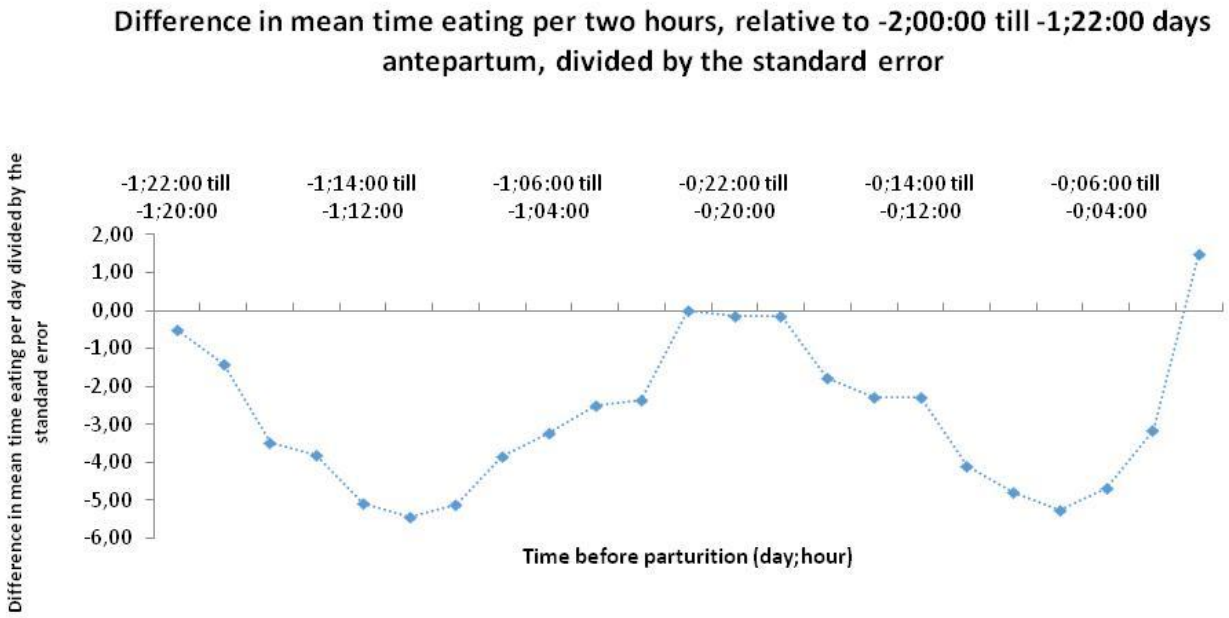

Figure 6. The standardized estimate of 23 of the 24 periods of two hours in the period; two days antepartum up to and including moment of parturition. To obtain the standardized estimate , the difference in mean time eating per day, relative to period -2;00:00 till -1;22:00 prior to calving was divided by the standard error. The first period, -2;00:00 till -1;22:00 was not displayed in the figure.

To get a better overview of what happens ten days antepartum up to and including four days postpartum, this time period was divided in sixty periods of six hours. All periods were compared to period -11;00:00 till -10;18:00. Results are presented in figure 7. Groups were classified on the basis of standardized estimate in figure 7.

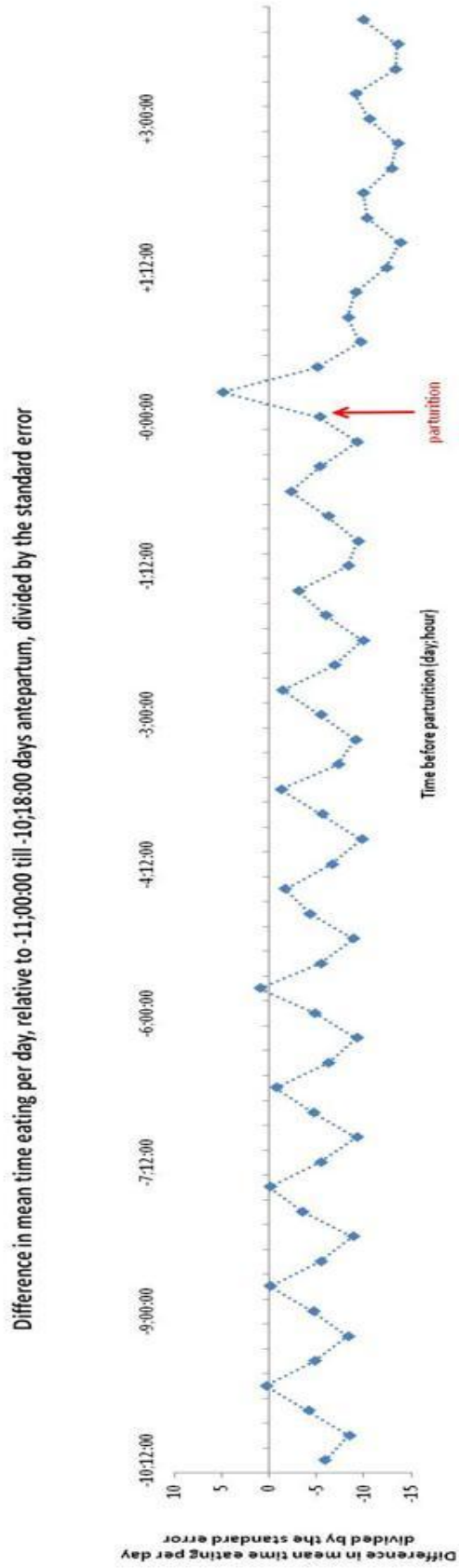

Figure 7. The standardized estimate of 59 of the 60 periods of six hours in the period; ten days antepartum up to and including four days postpartum. To obtain the standardized estimate, the difference in mean time eating per day, relative to period -11;00:00 till -10;18:00 prior to calving, was divided by the standard error. The first period, -11;00:00 till -10;18:00 was not displayed in the figure. The red arrow indicates the time of parturition.

The circadian rhythm was visible during the whole period of ten days antepartum up to and including four days postpartum. In the period of ten days up to and including five days antepartum the same amplitude was seen. At day four untill parturition the amplitude became smaller. Six hours postpartum the standardized estimate of the mean time eating per six hours became positive. This indicated an enormous increase in the mean time eating in the first six hours after giving birth to the calf. In the subsequent period the standardized estimate of the mean time eating per six hours was more negative and had a smaller amplitude than in the period before parturition. This indicates a decrease in the mean time eating in the first days after calving.

3.2 Eating behaviour postpartum

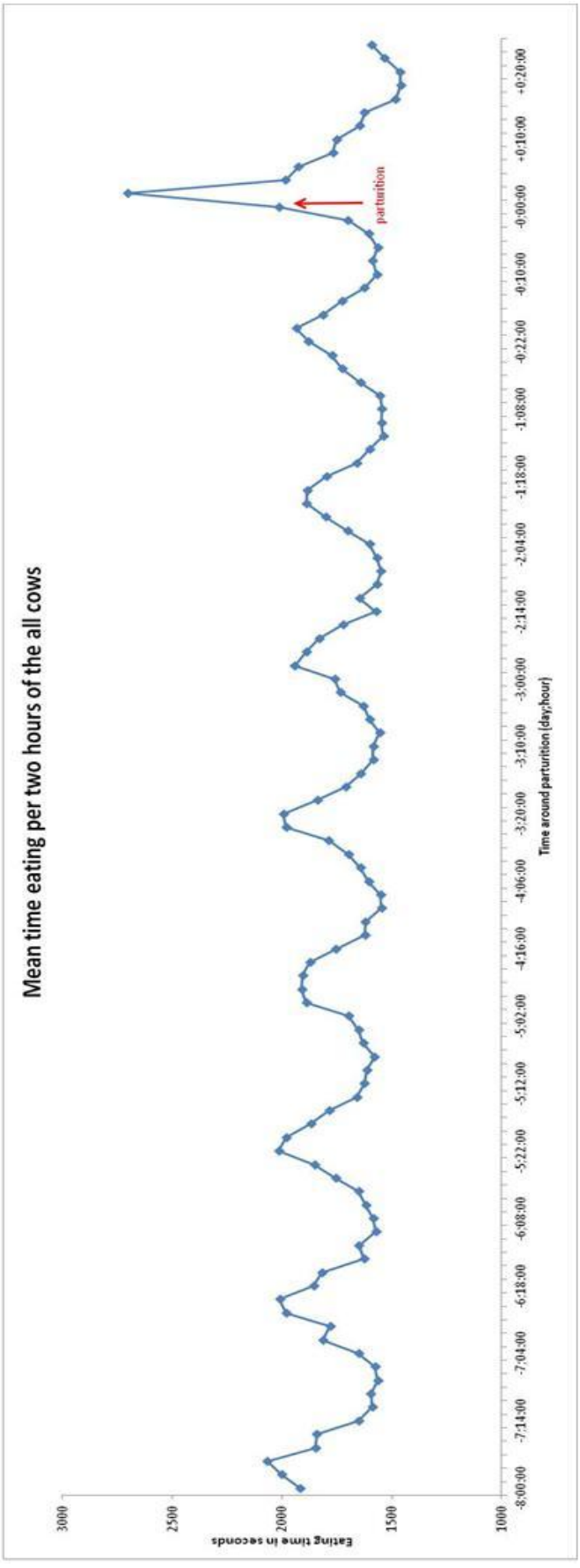

Figure 8. Mean time eating per two hours of 969 cows in the period eight days antepartum till one day postpartum. The red arrow indicates the time of parturition.

To analyze eating behaviour after calving data of 969 cows was used. In the two hours (+0;02:00) after parturition a mean time eating peak is registered by the Nedap Smarttag Neck. By comparing "real life" parturition with time spent feeding data, it was concluded, earlier in this study that licking of the calf is recorded by the data logger as time spent eating (Hut 2016 (unpublished data)). The amplitude of the circadian rhythm in the previous period is about 500 seconds (8.33 minutes). The mean time eating at +0;02:00 shows a peak that lies approximately 700 seconds (11.67 minutes) higher than the maximum average amplitude in the previous period.

The mean time eating, of 969 cows, is determined for the period -8;00:00 up to -6;00:00and also for the period -0;00:00 up to +2;00:00. The mean time eating in period -8;00:00 up to and including -6;00:00 is compared to the mean time eating in the two hours postpartum.

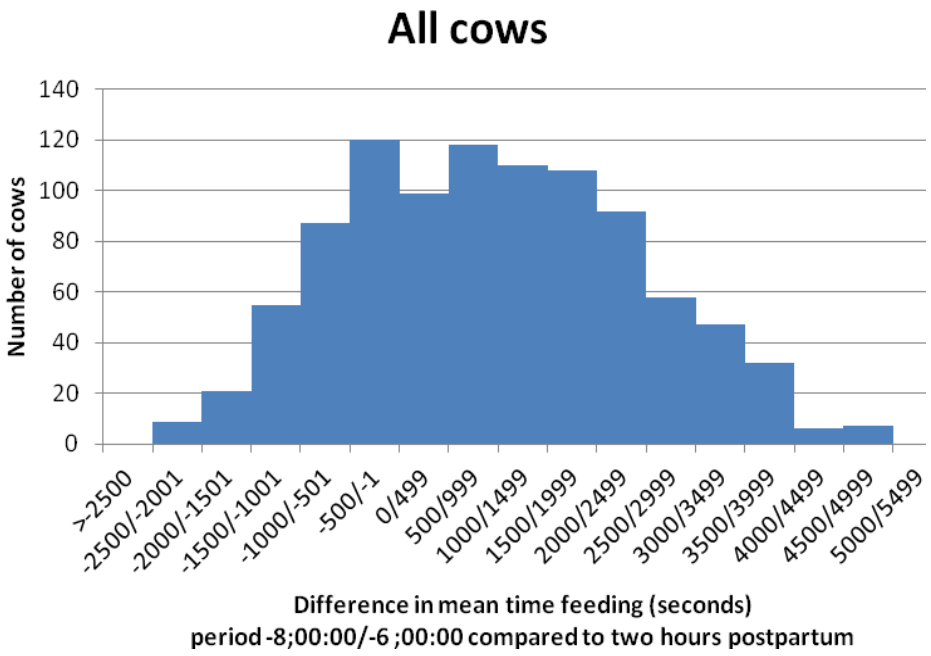

Figure 9. The distribution of the difference between mean time eating in period -8;00:00 up to and including -6;00:00 compared to the mean time eating two hours antepartum..

Cows showed on average a difference of 947.7(1459.8) seconds per two hours eating. With a 95% confidence interval of 91.9 seconds.

677 of the 969 cows show an increase in mean time eating when period-8;00:00 up to -6;00:00 is compared to the period two hours postpartum. This is 69.9%. So 30.1% of the cattle show a decrease in the mean time eating in when period -8;00:00 up to and including -6;00:00 is compared to period +0;02:00. Of these 677 cows, the period of two hours antepartum is compared with the period of two hours postpartum. 535 cows of the 677 animals show an increase in the mean time eating in the two hours after calving. This is 79.03% of the cattle. Of the 677 cows, 477 animals (70.5%) showed an increase in mean time eating of more than 500 seconds (8.33 minutes) in the period two hours after calving relative to -8;00:00 up to and including -6;00:00. Of the 535 animals that showed an increase in the period two hours postpartum, 477 cows (89,2%) showed an increase of more than 500 (8.33 minutes) seconds mean time eating. The group of 677 cows, that showed an increase in mean time eating when period-8;00:00 up to and including -6;00:00 was compared to the period two hours postpartum, contain 138 (20.4%) heifers and 539 79.6% multiparous cows. The group of 292 cows, that showed a decrease in the mean time eating in when period -8;00:00 up to -6;00:00 was compared to the period two hours postpartum, contain 76 (26.0%) heifers and 216 (73.9%) multiparous cows.

Data was divided into groups on basis of time of parturition. This was done to investigate if the time of calving affected the mean time eating in the two hours postpartum.

Table 5. Data on mean time eating of 969 cows divided on basis of time of parturition.

		Eating time (seconds)					
Group	**Time of calving**	**Mean**	**S.D.**	**Number of cows with increase <0**	**Increase <0**	**Number of cows with increase >500**	**Increase >500**
Group 1 (n=31)	24:00-01:59	1096.9	1696.1	11	35.0%	18	58.1%
Group 2 (n=32)	02:00-03:59	707.1	1683.55	11	34.4%	19	59.4%
Group 3 (n=48)	04:00-05:59	952.7	1504.4	6	12.5%	28	58.3%
Group 4 (n=89)	06:00-07:59	802.4	1310.5	23	25.8%	48	53.9%
Group 5 (n=111)	08:00-08:59	931.0	1349.9	34	30.6%	66	59.5%
Group 6 (n=100)	10:00-11:59	887.4	1587.9	35	35.0%	57	57.0%
Group 7 (n=94)	12:00-13:59	1047.4	1577.3	28	29.8%	61	64.9%
Group 8 (n=106)	14:00-15:59	1092.1	1521.9	29	27.4%	67	63.2%
Group 9 (n=108)	16:00-17:59	1178.8	1363.3	29	26.9%	67	62.0%
Group 10 (n=102)	18:00-19:59	979.7	1298.9	26	25.5%	66	64.7%
Group 11 (n=86)	20:00-21:59	772.3	1471.3	29	33.7%	48	55.8%
Group 12 (n=62)	22:00-23:59	718.8	1479.4	20	32.3%	33	53.2%

The difference in mean time eating among twelve groups, two hours postpartum, was analyzed (Table 6). P-values were not considered significant. Groups were classified on the basis of time of calving.

Table 6. Analysis of variance (ANOVA) of the mean time eating among twelve groups, with group as a fixed effect.

Time of parturition	Mean time eating per two hours	Std. Error	t-value	Pr(>|t|)
24:00 - 02:00	1096.90	262.43	4.18	3.18e-05***
02:00 - 04:00	-389.82	368.22	-1.06	0.29
04:00 - 06:00	-144.20	336.67	-0.43	0.67
06:00 - 08:00	-294.49	304.72	-0.97	0.33
08:00 - 10:00	-165.88	296.82	-0.56	0.58
10:00 - 12:00	-209.47	300.36	-0.70	0.49
12:00 - 14:00	-49.54	302.62	-0.16	0.87
14:00 - 16:00	-4.79	298.34	-0.02	0.99
16:00 - 18:00	81.94	297.72	0.28	0.78
18:00 - 20:00	-117.22	299.66	-0.39	0.70
20:00 - 22:00	-324.59	306.09	-1.06	0.29
22:00 - 24:00	-378.15	321.40	-1.18	0.24

Of all the 969 cows, 28.9% of the animals showed a decrease in mean eating time in period -8;00:00 up to and including -6;00:00 relative to two hours antepartum and an increase in mean time eating in the two hours after parturition. This increase in mean time eating in two hours after calving varies from 161 seconds (2.68 minutes) to 5639 seconds (93.98 minutes). Of all 969 cows, 28.3% showed a decrease in mean time eating in period -8;00:00 up to -6;00:00 relative to period -0;00:00 and an increase in mean time eating of more than 500 seconds in the two hours after giving birth to the calf.

The difference in mean time eating, two hours postpartum, among heifers and multiparous cows was analyzed. P-values were not considered significant.

Table 7. Analysis of variance (ANOVA) of the mean time eating among heifers and cows.

	Mean time eating two hours postpartum	Std. Error	t value	Pr(>|t|)
Multiparous cows	984.20	53.1	18.54	<2e-16***
Heifer	-165.40	113	-1.46	0.14

The increase in mean time eating , two hours postpartum, was also analyzed using a two factor ANOVA with interaction (Table 10). P-values were not considered significant.

Table 10. Mean time eating two hours postpartum analyzed using a two factor ANOVA with interaction.

	Mean time eating two hours postpartum	Std. Error	t value	Pr(>|t|)
Multiparous cows time of parturition 24:00 - 02:00	1185.37	309.58	3.83	0.00 ***
Heifer time of parturition 24:00 - 02:00	-304.73	574.55	-0.53	0.60
Multiparous cows time of parturition 02:00 - 04:00	-414.76	433.02	-0.96	0.34
Multiparous cows time of parturition 04:00 - 06:00	-148.70	383.75	-0.39	0.70
Multiparous cows time of parturition 06:00 - 08:00	-158.15	358.16	-0.44	0.66
Multiparous cows time of parturition 08:00 -10:00	-349.26	343.56	-1.02	0.31
Multiparous cows time of parturition 10:00 -12:00	-78.00	350.04	-0.22	0.82
Multiparous cows time of parturition 12:00 - 14:00	-146.60	352.61	-0.42	0.68
Multiparous cows time of parturition 14:00 - 16:00	-101.00	348.64	-0.29	0.77
Multiparous cows time of parturition 16:00 - 18:00	-92.83	347.76	-0.27	0.79
Multiparous cows time of parturition 18:00 - 20:00	-290.38	350.53	-0.83	0.41
Multiparous cows time of parturition 20:00 -22:00	-271.58	357.47	-0.76	0.45
Multiparous cows time of parturition 22:00 - 24:00	-415.66	376.40	-1.10	0.27
Heifers time of parturition 02:00 - 04:00	78.84	809.97	0.10	0.92
Heifers time of parturition 04:00 - 06:00	-271.02	826.28	-0.33	0.74
Heifers time of parturition 06:00 - 08:00	-528.94	671.12	-0.79	0.43
Heifers time of parturition 08:00 -10:00	963.18	695.76	1.38	0.17
Heifers time of parturition 10:00 -12:00	-742.59	676.17	-1.10	0.27
Heifers time of parturition 12:00 - 14:00	345.09	681.19	0.51	0.61
Heifers time of parturition 14:00 - 16:00	338.92	666.09	0.51	0.61
Heifers time of parturition 16:00 - 18:00	693.09	665.63	1.04	0.30
Heifers time of parturition 18:00 - 20:00	664.68	667.08	1.00	0.32
Heifers time of parturition 20:00 -22:00	-303.65	683.72	-0.44	0.66
Heifers time of parturition 22:00 - 24:00	107.25	712.55	0.15	0.88

The 969 cows contain 214 (22.1%) heifers and 755 (77.9%) multiparous cows. Of all heifers, 148 (69.2%) showed an increase in mean time eating in the two hours postpartum. This increase varied from 16 seconds (0.27 minutes) to 5499 seconds (91.7 minutes). 128 (59.8%) of all 214 heifers showed an increase of more than 500 seconds (8.33 minutes) mean time eating in the two hours postpartum. Of all heifers, 97 (45.3%) primiparous cows showed a decrease in period -8;00:00 up to -6;00:00 relative to two hours antepartum and an increase in the two hours after calving.

The 969 cows contain 755 (77.9%) multiparous cattle. Of these older cows, 481 (63.7%) of the 755 animals showed an increase in the two hours postpartum. This increase varied from two seconds (0.03 minutes) to 5639 seconds (94.0 minutes). Of the 481 multiparous cows, 401 (53.1%) cows showed an increase of more than 500 seconds (8.33 minutes) mean time eating in the two hours postpartum. Of all multiparous cows, 229 (30.3%) cows showed a decrease in the period -8;00:00 up to -6;00:00 relative to two hours before calving and an increase in the two hours postpartum.

4. Discussion

4.1.1 Eating time before parturition

In the original database ,data of 3375 cows were available. Cattle with missing or inconsistent data were excluded from this study. At first it looked like it was approximately a quarter of all collected data. As the study progressed more cattle were excluded from the dataset due to missing data and eventually 527 cows remained in the database for the first goal of the study and 969 cows remained in the study for the second, third, fourth and fifth goal of the study. This could be due to wrong attached sensors, a collar that was to loose or administrative errors in Velos®. Another reason was that the data from the data logger could not be read out within 24 hours because the cow was outside the range of the antenna (cows were outside).

In the present study the estimated time of calving was included. Therefore, there were small deviations in the exact time of parturition. This could be the reason that the standardized estimate, in figure 5, six hours antepartum is less negative than in period twelve to six hours prior to calving, which indicates an increase in mean time eating in the last six hours antepartum. The increase in the mean time eating, visible in figure 5, appears to be caused by the increase of the mean time eating in the last two hours before parturition (Figure 6). Possibly the exact time of parturition was not documented properly for several cows and this 'increase in time spent eating' is probably caused by the licking of the calf postpartum. Another reason could be that cattle are feeding less in the hours prior to parturition, but they do not totally stop feeding (Jensen 2012). Wehrend, Hofmann et al. (2006) reported that the rupture of the amniotic sac led to a relief causing some cattle to start feeding after rupture.

In this study no distinction is made between assisted and unassisted births. By including assisted births, cases of dystocia will be included. Depending on the reason of dystocia, the behaviour of the cow in the periparurient period will be influenced. Proudfoot, Huzzey et al. (2009) demonstrated that cattle that had a difficult calf delivery reduced water and feed intake and also time spent feeding reduced two days antepartum.

In the present study no consideration is taken for lameness of cattle. In several studies, cattle with more severe lameness, spent less time eating per day (Palmer, Law et al. 2012, González, Tolkamp et al. 2008, Norring, Häggman et al. 2014, Bach, Dinarés et al. 2007). Severely lame cattle also feed faster (Norring, Häggman et al. 2014).

Illness was also not taken into account in this field study. For instance cows with subclinical ketosis had a lower dry matter intake in the week before parturition and two weeks postpartum (Goldhawk, Chapinal et al. 2009). The present study only investigated the time spent feeding to predict time of parturition. Other authors reported relations with DMI (Schirmann, Chapinal et al. 2013), rumination activity (Schirmann, Chapinal et al. 2013, Ouellet, Vasseur et al. 2016, Pahl, Hartung et al. 2014), clinical signs (Streyl, Sauter-Louis et al. 2011), progesterone rapid blood test (PRBT) (Streyl, Sauter-Louis et al. 2011), lying behaviour (Miedema, Cockram et al. 2011a, Jensen 2012, Ouellet, Vasseur et al. 2016), tail rising (Miedema, Cockram et al. 2011a), activity (Jensen 2012), mean vaginal temperature (Ouellet, Vasseur et al. 2016) or body temperature (Streyl, Sauter-Louis et al. 2011).

Of all the 969 cows, 28.9% of the animals showed a decrease in mean eating time in the two hours prior to calving relative to period -8;00:00 till -6;00:00 and an increase in mean time eating in the two hours after parturition. Bertics, Grummer et al. (1992) reported a decline in feed intake of 28% one week antepartum compared to three weeks before parturition. According to Schirmann, Chapinal et al. (2013) DMI decreased by 24% in the 24 hours before parturition compared to two to four days antepartum. This decline in dry matter intake and time spent feeding was primarily observed within eight hours of parturition (Schirmann, Chapinal et al. 2013). This corresponds with the findings of Miedema, Cockram et al. (2011b). Miedema, Cockram et al. (2011b) summarized data, concerning time spent feeding, in six hour periods and each period was compared with the same

period the day before. A decrease in time spent feeding was reported in the six hours antepartum. According to Schirmann, Chapinal et al. (2013) dry matter intake recovered in six hours postpartum. No significant decrease could be demonstrated in the present study but an average decline in time spent feeding was visible in the last ten days before calving. This decline became more prominent around day four until parturition. This data was found by using the mean time eating of 969 cows. Individual animals showed different eating patterns and the distribution of the individual mean time eating was very large, so only using time spent eating to predict parturition is not reliable.

4.1.2 Predicting the time of parturition

In the study of Streyl, Sauter-Louis et al. (2011) relaxation of the broad pelvic ligaments combined with teat filling gave the best predicting values for parturition or no parturition within twelve hours. On basis of different clinical signs, (relaxation of the broad pelvic ligaments, vaginal fluid discharge, physiological hyperplasia of the udder, edema of the udder, filling of the teats, relaxation of the tail and edema of the vulva) a parturition score (PS) was established (Streyl, Sauter-Louis et al. 2011). Below a threshold of four PS point parturition within 12 hours could be ruled out with a probability of 99.3% in multiparous cows (95.5% in first-calf heifers) (Streyl, Sauter-Louis et al. 2011). Above the threshold of four points, calving monitoring every three hours and a progesterone rapid blood test (PRBT) was recommended (Streyl, Sauter-Louis et al. 2011). By combining PS and PRBT, prediction of parturition within 12 hours improved from 14.9% to 53.1% (Streyl, Sauter-Louis et al. 2011). The probability of ruling out parturition was 96.8% (Streyl, Sauter-Louis et al. 2011). Ouellet, Vasseur et al. (2016) however believed that assessment of clinical signs are subjective and time consuming, also these signs can vary enormously between cattle.
Not only eating behaviour can be measured by Nedap Smarttags, lying behaviour can also be measured. For registering lying behaviour the Nedap Smarttag Leg can be used. In the study of Ouellet, Vasseur et al. (2016) lying behaviour is used to predict the onset of calving. A decrease in rumination time and an increase in lying bouts is demonstrated, in the last six hours antepartum (Ouellet, Vasseur et al. 2016). Lying time, however, showed a minimum in the period of twelve to six hours before parturition whereas vaginal temperature showed a decline in the period of eighteen to twelve hours prepartum (Ouellet, Vasseur et al. 2016). This makes it difficult to compute an optimum cut-off point for all the cattle but combining calving indicators can enhance the strength of each individual indicator (Ouellet, Vasseur et al. 2016). Ouellet, Vasseur et al. (2016) recommend the combination of rumination time and lying bouts for a prediction concerning a possible parturition in the next six hours.

4.2 Eating behaviour postpartum

4.2.1 Licking the calf

After giving birth to the calf, the predominant behaviour of the cow is licking the calf (Edwards and Broom, 1982). During this study “real life” parturition was compared with the registered time spent feeding, it was concluded, that licking of the calf is recorded by the data logger as time spent eating. Probably the movement and position of the head, while eating, corresponds with the movement and position of the head while licking the calf. Licking occupies most of the time the first hour postpartum and decreases with time postpartum (Edwards and Broom, 1982) (Jensen 2012). Edwards and Broom (1982) showed a drop of more than 50% from the first to the second hour after calving. Heifers spent less time licking their calves than second and third calvers (Edwards, Broom 1982). This was due to the smaller amount of time spent licking the calf in the first hour

postpartum (Edwards and Broom, 1982). In the second hour postpartum heifers partially compensated the lower initial licking because they licked their calves more than older cows (Edwards and Broom, 1982). In the study of Edwards, Broom (1982) only heifers showed total failure to lick the calf. No significant difference between heifers and multiparous cows was found in the present study. The time between parturition and resumption of feeding decreased with parity (Edwards, Broom 1982). During the present field study it was observed that the eating peak as recorded in the two hours postpartum was, in fact, due to the licking of the calf. While eating or licking, the cow makes the same movements with the head. No data is available on when the calf was separated from the dam, so there can be large differences in this dataset between the exact time of removal. It is hard to say if the registered movement was actually licking or eating. Less time feeding is spent during the first hour postpartum (Jensen 2012). Feeding behaviour gradually increased from the second hours after calving (Jensen 2012). Of the 969 cows, 677 (69.9%), in the present study, showed an increase in mean time eating when period -8;00:00 up to and including -6;00:00 is compared to two hours postpartum. It is assumed that these animals are given the opportunity to exhibit their natural behaviour (licking the calf). This would mean that 30.1% are not able to exhibit natural behavior because of several reasons e.g. health reasons or rapid removal of the calf.

5. Conclusion

Eating showed a circadian rhythm. A decline in time spent eating is recorded in the ten days antepartum and an even more prominent decline is observed in the last four days before calving. An enormous increase in time spent eating is registered in the first two hours postpartum. This peak in time spent eating is actually the licking of the calf. No significant difference in licking/eating behaviour could be found between heifers and multiparous cows nor in the time of calving. In further study, estimated calving time should be excluded and only exact time of parturition should be included.

Time spent eating could be used as one of the parameters to predict the time of parturition or to demonstrate that the calf is born, but only registering feeding time is not enough. Lying behaviour, ruminating activity, DMI and also clinical signs could be a good addition. Refinement of registration of behaviour data would be an improvement to get a better view in changes in behaviour before and after parturition. So electronic data loggers could be useful tools to assist management in the periparturiant period but further study is necessary.

6. Acknowledgements

The author wishes to extend thanks to all the farmers participating in the Nedap-Vetvice-WUR-UU project for kindly permitting us access to their dairy farm. The author also warmly thanks; drs. P.R. Hut and dr. F.J.C.M. van Eerdenburg for their supervision during the research internship and dr. J. van den Broek and J.C.M. Vernooij for their statistical support.

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