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Rumination activity of dairy cows in the 24 hours before and after calving

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ABSTRACT

Monitoring rumination behavior serves multiple purposes in feeding and herd management of dairy cows. The process of calving is a major event for cows, and a detailed understanding of alterations in behavioral patterns of animals in the time around calving is important in calving detection. The objective of this study was to describe the short-term changes in rumination patterns in dairy cows immediately before and after parturition. In total, 17 cows were fitted with rumination sensors that were able to monitor rumination time, number of rumination boli, and number of rumination jaw movements. Rumination time was decreased in the last 4 h antepartum and in the first 8 h postpartum. Cows stopped ruminating 123 ± 58 min (mean ± standard deviation) before calving and resumed ruminating 355 ± 194 min after calving. The number of rumination jaw movements and boli per day were decreased in the 24-h period postpartum. Rumination rate, the number of rumination jaw movements per rumination minute, and the number of boli per rumination minute changed little around calving. The calving event primarily influenced the duration and frequency of various rumination characteristics but not rumination intensity. Among detected characteristics, rumination time showed the greatest potential for monitoring of calving events.
Key words: rumination behavior, calving, sensor, boli, jaw movement

INTRODUCTION

Detailed knowledge about changes in animal behavior around calving helps to identify time periods with a special need for observation. It is well known that DMI (Bertics et al., 1992) and rumination time (Soriani et al., 2012) of dairy cows decrease considerably in the last week before calving. In general, the days around calving are characterized by decreased feeding time along with an increased number of standing bouts and standing time (Huzzey et al., 2005). The calving event itself is announced by typical behavior patterns of cows in the first stage of labor (Wehrend et al., 2006). Streyl et al. (2011) found that, among physiological indicators, the combination of relaxation of ligaments and filling of teats delivered the best results for improvement of calving prediction.

Rumination activity records of cows can fulfill different purposes. In animal nutrition, rumination characteristics are commonly used to quantify structure content in varying ration compositions (Beauchemin and Yang, 2005). Decrease in rumination duration is described as an indicator of stress (Herskin et al., 2004) or is found during estrus in dairy cows (Reith and Hoy, 2012). Siivonen et al. (2011) indicated the potential of rumination time as an indicator for health disorders. To date, only sparse data describe the effects of calving on rumination activity. Bar and Solomon (2010) reported a decrease in daily rumination time of around 255 min during the day of calving. Similar results were reported by Soriani et al. (2012), who found a clear reduction of daily rumination time in the days close to calving and denoted the ability of rumination time as possible indicator for detecting calving events or health disorders. Latest studies reported that rumination time was decreased particularly during the last 6 h (Büchel and Sundrum, 2014) and 4 h (Schirmann et al., 2013) antepartum, respectively. The objectives of the current study were to evaluate the course of rumination time at a high temporal resolution before and after parturition; to gain additional information on further rumination characteristics, such as number of rumination boli and rumination jaw movements; and to investigate the length of rumination periods and breaks close to the calving event.

MATERIALS AND METHODS

The research study was conducted at the federal state research farm LVZ Futterkamp (Schleswig-Holstein, Germany). The farm milked around 190 German Holstein cows with an average herd yield of 10,700 kg

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of milk/305 d (3.9% milk fat and 3.2% milk protein) during the trial period. Data were recorded between March and May 2012.

Animals, Housing, and Feeding

The rumination behavior of 17 cows around parturition was monitored. Cows involved in the trial were in their first to fourth lactations: first (n = 1), second (n = 9), third (n = 3), and fourth (n = 4). None of the cows involved in the study suffered from acute health disorders during the trial. Dry cows were housed in a freestall barn until approximately 2 wk before expected calving and then relocated to straw-bedded, 20-m^2 maternity pens. One to 3 cows were kept per maternity pen depending on the actual number of parturitions at a time but were separated when physiological signs indicated imminent parturition. During their stay in the maternity pen, cows were fed a TMR and offered water ad libitum. Cows included in the trial until the end of March (n = 10 cows) received a ration consisting of 62.4% corn silage, 28.5% grass silage, 7.9% concentrate, 0.7% straw, 0.3% minerals, and 0.2% calcium carbonate. The ration fed beginning in April changed marginally due to structural conditions on the research farm and contained 58.7% corn silage, 32.7% grass silage, 7.5% concentrate, 0.7% straw, 0.3% minerals, and 0.2% calcium carbonate (n = 7 cows). Individual cows in trial continuously received the same ration.

Calving Event

Calving events were monitored and documented by the farm staff. A calving event was regarded as finished when both back legs were outside the cow ("time of calving"). Day, time of calving, calving difficulty, and sex of calf were documented. Calving events were classified as easy (0, no help required), medium (1, slight help required), or difficult (2, mechanical help required). Newborn calves received the first colostrum donation in the maternity pen and were moved to a separate pen 1.5 to 2 h after calving. Cows stayed in the straw boxes to recover for a few days and were moved to the lactating herd when having no apparent health problems.

Rumination Recording

The collection of rumination data was conducted by using 4 rumination sensors (ART-MSR; Agroscope Reckenholz-Tänikon, Ettenhausen, Switzerland). Cows were equipped with a rumination sensor as soon as their physiological constitution indicated imminent parturition within the next few days, and sensors were removed when cows left the maternity pen. In particular, the physiological indicators considered decisive for sensor onset were relaxation of pelvic ligaments and udder filling. On average, the sensors were attached to the cows for 79 h before calving (minimum 20 h; maximum 210 h). Delays in the onset of rumination records per cow occurred occasionally because of an unexpected early calving event or shortage of sensor availability.

The rumination sensors consisted of a modular signal recorder (MSR 145 logger, MSR Electronics GmbH, Seuzach, Switzerland) and a noseband sensor (Nydegger et al., 2010). The measurement principle was pressure based, and thus differed from acoustic sensors used in previous studies of, for example, Schirmann et al. (2013). Results on the accuracy of the 2 different sensor types when compared with direct observation can be found in Pahl et al. (2012). The pressure sensor was fixed above the nose of the cow and the logger registered and stored pressure shifts caused by jaw movements of the animal with a frequency of 10 Hz. The logger has a maximal storage capacity of 40 h, but transfer of raw data from logger to PC was conducted daily during the trial. Each enclosed period of recorded raw data formed a measuring section and had a length of approximately 24 h. The evaluation of raw data was performed with R-based Bioconductor software (R, Boston, MA). For each of the measuring sections, characteristic sequences (about 5 to 10 min per section) for the activities "rumination" and "feeding" were defined as learning data files and these were then utilized by the program to classify raw pressure data (Nydegger et al., 2010). No further adaptation time for calibration of sensors was required. Resulting rumination characteristics of the data classification were rumination time, number of rumination boli, and number of rumination jaw movements.

The software for analysis of pressure data aggregated the raw data in freely selectable evaluation periods, which in the current study were 2-h and 24-h periods. In addition, the raw data set was used to evaluate the length of single rumination periods and breaks between rumination periods close to the calving event. Thereby, start and end of rumination periods were labeled with a time resolution of 1 min. The characteristic decrease of pressure caused by regurgitation of the first bolus was defined as the start, and swallowing of the last bolus signaled the end of a rumination period. As rumination patterns usually change shortly around calving, the duration of the last 3 rumination periods before and first 3 periods after the calving event were considered most promising for evaluation. Furthermore, the following were analyzed: the lengths of breaks between third and second-last rumination period (antepenultimate break), between second-last and last rumination period (penultimate break), between last rumination period

and calving (ultimate break), between calving and first subsequent rumination period (first break), between first and second rumination period (second break), and between second and third rumination period (third break) after calving. Raw data for the evaluation of rumination periods and breaks close to the calving event were analyzed consistently by 1 analyst.

Because of late onset of rumination sensors before parturition (<48 h antepartum) in 3 of the 17 cows, those calving events (1 easy male, 1 medium male, 1 difficult male) were included only in the evaluation of the length of rumination breaks and rumination periods shortly before and after parturition, but not in analysis of reference period, 24-h period antepartum, and 24-h period postpartum.

Statistical Analysis

The recorded rumination characteristics (rumination time, number of rumination boli, and number of rumination jaw movements) were analyzed in periods of 2 h in the first step. The 2-h period in which calving took place was defined as period zero and was excluded from 24-h periods. The time lag between the beginning of period zero and parturition varied as cows did not give birth to calves at the same time. This means that calving events were positioned nonuniformly within the 2-h calving periods. The twelve 2-h periods before calving formed the 24-h period antepartum (−24, −22, −20, ..., −02), the twelve 2-h periods after calving were defined as the 24-h period postpartum (+00, +02, ..., +22). Rumination records preceding the 24-h period antepartum formed a 24-h reference (**ref**) period ($_{ref}$24, $_{ref}$22, $_{ref}$20, ..., $_{ref}$02). The 2-h values in the reference period were averaged if applicable from several days (i.e., all records preceding the 24-h period antepartum were considered). The hours of the 24-h reference period were matched to the corresponding hours of the antepartum and postpartum periods. This means that period $_{ref}$24 was compared with period −24 and period +00 and period $_{ref}$22 with −22 and +02. Finally, data of the 2-h periods were summed and evaluated in 24-h periods as well.

The program used for statistical analysis was PASW 18.0 (IBM SPSS; IBM Corp., Armonk, NY). Variables were checked for normal distribution by the Kolmogorov-Smirnov test. Rumination characteristics per cow in the reference period and the days of interest were considered as pairs and analyzed with Friedman's test for more than 2 variables or Wilcoxon signed rank test for 2 variables. The influence of 2 independent group variables, in this case, calving difficulty, on the results was analyzed by the Mann-Whitney U test. As just one calving event was classified as difficult, only easy and medium calving events were tested for their effect. The level of significance was $P < 0.05$ in all tests.

RESULTS

Eight calving events took place between 0400 and 1200 h, 8 occurred between 1600 and 2400 h, and 1 occurred between 1200 and 1400 h. Calving events were classified as easy (female calves = 5, male calves = 7), medium (female calves = 0, male calves = 4), and difficult (female calves = 0, male calves = 1).

Reference Period

The average values for rumination time during the reference period ranged between 25.3 min/2-h period (SD: 14.9; $_{ref}$24) and 42.2 min/2-h period (SD: 20.4; $_{ref}$18; Figure 1). As calving events were distributed irregularly throughout the day, the 2-h periods showed no characteristic circadian pattern (Figure 1). Nevertheless, the comparison of period $_{ref}$04 to period $_{ref}$02 resulted in a decrease in rumination time (Wilcoxon test, $P = 0.041$).

Cows masticated on average between 68.7 (SD: 8.5; $_{ref}$14) and 72.2 (SD: 5.3; $_{ref}$16) rumination jaw movements per rumination minute. The number of rumination boli per rumination minute varied between 1.2 (SD: 0.2; $_{ref}$06) and 1.4 (SD: 0.3; $_{ref}$02).

The average rumination time per cow per 24 h was 397 min (SD: 86 min) during the reference period. In the course of the day, most of the cows ruminated the least (per 2-h period) between 0800 and 1400 h, whereas the longest rumination time per 2-h period occurred in most cows between 2200 and 0400 h. On average, 481 rumination boli (SD: 124) and 28,874 rumination jaw movements (SD: 7,915) per cow per 24 h were masticated during the reference period.

Antepartum Period

During the 24 h immediately before calving, rumination time lasted between 19.1 min/2-h period (SD: 9.0; period −02) and 45.1 min/2-h period (SD: 18.0; period −22). Comparison of period −06 to $_{ref}$06, period −04 to $_{ref}$04, and period −02 to $_{ref}$02 displayed reduced rumination time immediately before calving. Statistical differences were localized particularly in period −04 (Wilcoxon test, $P = 0.023$) and −02 (Wilcoxon test, $P = 0.006$), but not in period −06 (Wilcoxon test, $P = 0.071$). The number of boli per rumination minute was not changed in any of the 2-h periods when comparing those of the reference period and the 24-h period antepartum. However, rumination jaw movements per

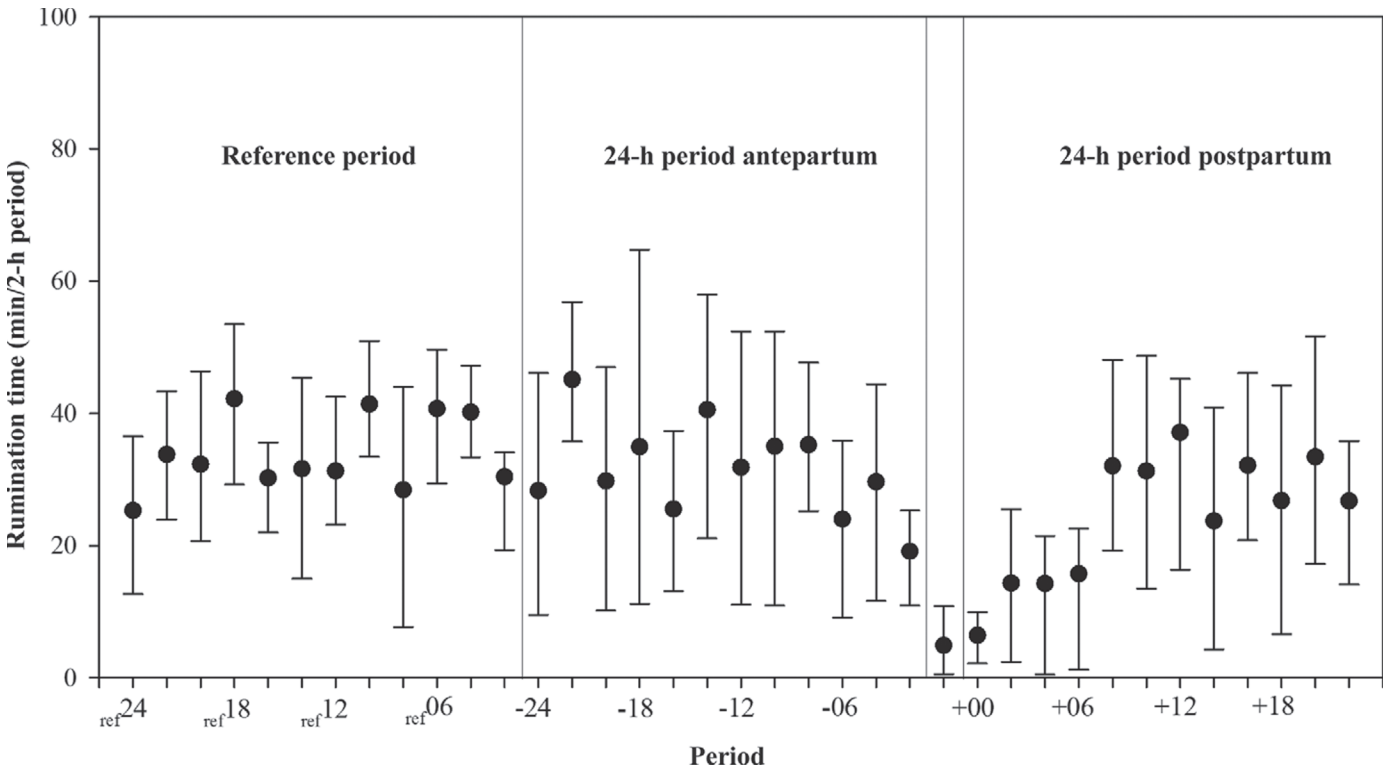

Figure 1. Medians (●) and quartiles (whiskers) of rumination time in 2-h periods during the reference period ($_{ref}24$, $_{ref}22$, …, $_{ref}02$), the 24-h antepartum period (−24, −22, …, −02), the calving period, and the 24-h postpartum period (+00, +04, …, +22).

rumination minute were increased in the period −08 (Wilcoxon test, $P = 0.037$) antepartum.

The values for the 24-h antepartum period on daily rumination time (374 min, SD: 110 min), number of boli per day (446 boli, SD: 128 boli), or number of rumination jaw movements (27,983, SD: 8,995) did not differ from those of the reference period. Differences in number of boli per rumination minute and number of rumination jaw movements per rumination minute between the 24-h antepartum period and reference period were insignificant.

On average, 123 min elapsed between the end of the last rumination period and the calving event (Table 1). Values for duration of the final break showed a huge variance per cow (17 to 220 min). Nine of 17 cows stopped ruminating more than 2 h before calving and 3 cows were ruminating less than 1 h before parturition. The break between the last rumination period and calving tended to be longer than the 2 preceding breaks (Friedman's test, $P = 0.059$, Table 1). Although the last rumination period before calving was, on average, approximately 10 min shorter than the others, the difference was statistically insignificant. For 9 cows, the penultimate rumination period was longer than the ultimate rumination period; for 8 cows, the opposite was true. The length of rumination breaks and rumination periods before and after calving did not vary according to easy or medium calving difficulty.

Postpartum Period

During the 24-h period postpartum, rumination time varied between 6.4 min/2-h period (SD: 5.9 min; +00) and 37.1 min/2-h period (SD: 28.3 min; +12). Rumination time per 2-h period postpartum was lower in periods +00 (Wilcoxon test, $P = 0.011$), +02 (Wilcoxon test, $P = 0.011$), and +06 (Wilcoxon test, $P = 0.036$) compared with the reference period. Both rumination jaw movements per rumination minute and boli per rumination minute did not differ between the reference period and 24-h postpartum period.

Rumination time summed to 278 min (SD: 64 min) in the 24 h after calving and hence was clearly reduced compared with the reference period and the 24-h period antepartum (Wilcoxon test, $P = 0.025$). In addition, a significant reduction was found for number of boli per 24 h postpartum (378 boli, SD: 130; Wilcoxon test, $P = 0.018$) and the number of rumination jaw movements per 24 h postpartum (20,958, SD: 5,945; Wilcoxon test, $P = 0.028$).

The first rumination period after parturition was shorter than the third rumination period postpartum

Table 1. Average duration (±SD) of last (first) 3 rumination periods and last (first) 3 breaks in rumination before (after) calving

	Antepartum		
Activity	Antepenultimate	Penultimate	Ultimate
Length of rumination period (min)	33.5[a] ± 19.1	32.9[a] ± 16.8	22.3[a] ± 12.5
Length of break (min)	84.9[a] ± 54.8	81.3[a] ± 43.0	122.9[a] ± 58.2
	Postpartum		
	First	Second	Third
Length of rumination period (min)	24.6[a] ± 26.8	27.8[ab] ± 19.3	30.8[b] ± 12.6
Length of break (min)	355.1[a] ± 193.9	90.4[b] ± 143.6	60.3[b] ± 34.3

[a,b]Values with different superscripts indicate significant differences within a row (Friedman test, $P < 0.05$).

(Table 1). On average, it took 355 min until cows resumed ruminating after giving birth to the calf (Table 1). Length of breaks per cow between calving and the first rumination period after calving ranged from 42 to 726 min. Except for 3 cows with a very short break after calving, the rumination break in all other animals lasted more than 3 h postpartum. Consequently, the first break postpartum was longer than all other considered breaks (Table 1). The durations of the second and third rumination breaks after calving were significantly shorter than the first one.

DISCUSSION

Influences on rumination behavior can be attributed to 3 main groups of reasons for variation: feeding, animal, and environment (Richter, 2010). Factors from these groups interact with each other and their interaction is responsible for the wide range of rumination data in literature (Richter, 2010). Rumination time in the reference period of the current study was less than that in dry cows of Aikman et al. (2008) or Soriani et al. (2012). Aikman et al. (2008) measured a longer rumination time per day for lactating cows than for dry cows but dry cows ruminated significantly more intensely (min/kg of DM) and with a higher frequency (boli/min) compared with lactating cows in the first weeks after calving. Rumination frequency and rumination rate have rarely been described in the literature, and changes from dry to lactating cows as described by Aikman et al. (2008) are probably more associated with altered metabolic processes than with the calving event itself.

In the days and hours before and after calving, dairy cows obviously change their behavior. Bertics et al. (1992) found a decrease in feed intake of nearly 30% in the last week before parturition. Rumination time declines progressively in the week before parturition (Bar and Solomon, 2010; Soriani et al., 2012), and rumination time on the day of calving was reduced by more than 3 h compared with the dry period (Soriani et al., 2012). The reference period chosen in the present study immediately preceded the 24-h antepartum period to ensure detection of short-term changes in rumination activity. Significant alterations in number of rumination jaw movements per rumination minute and in rumination time were found not earlier than 4 to 8 h before parturition in the current study. Only the last rumination break before parturition was prolonged compared with preceding ones. The decrease in rumination time was more than 10 min/2-h period in the 3 last 2-h periods antepartum.

Restlessness in cows before calving is well known and illustrated by, for example, an increase in the number of standing bouts (Huzzey et al., 2005) or lying bouts (Miedema et al., 2011b). Miedema et al. (2011a) compared changes in the behavior of cows in the 24 h before calving with behavior in late pregnancy. The last 24 h before calving was characterized by increases in lying frequency, walking frequency, and tail raising frequency (Miedema et al., 2011a). Significant shifts in those behaviors were found in the last 6 h before calving and hence are in temporal accordance with the antepartum decline in rumination activity in the present study. Jensen (2012) found an increase in lying bouts and activity in the last 6 h before calving, whereas the highest values for lying bouts and head-turning frequency were found in the last 2 h before calving. This is also the time period in which cows stopped ruminating in the current study, 123 min, on average, before the calf was finally delivered. Next to reduced rumination time, the importance of the last 2-h period is underlined by the complete cessation of rumination activity. It is hence the most promising time slot to indicate upcoming calving events. The cessation of rumination activity before parturition was between the beginning of restlessness, 197 min before calving, and the onset of labor, 106 min before calving, as described by Berglund et al.

(1987). Differences in rumination time between the reference period and the 24-h period antepartum were not found for evaluation of 24-h periods but were for 2-h periods. Thus, our results emphasize the importance of evaluating rumination behavior with a high temporal resolution.

Rumination time, number of rumination jaw movements, and number of boli were reduced in the 24-h period after calving compared with the reference period in the current study. Rumination time of cows was decreased in the first 8 h after parturition and returned to the base level of the reference period subsequently. The 2-h period with the lowest rumination activity was the first 2-h period after calving (6.4 min/2 h). This was in accordance with the shortest lying, feeding, and drinking durations combined with most cow-calf interactions in the first hour after calving in investigations of Jensen (2012). The onset of reduction in rumination time was similar to the latest findings of Schirmann et al. (2013). In the current study, rumination time started to decrease 6 h before calving and was reduced significantly in the last 4 h antepartum. The reduction of rumination activity in the current study lasted until 8 h postpartum and hence persisted 4 h longer than in Schirmann et al. (2013). Resumption of rumination activity after calving is directly linked to the start of feed intake. Schirmann et al. (2013) reported recovery of DMI 6 h after calving, which might explain the duration until resumption of rumination activity after calving observed in the present study. The similarity of the findings in the study of Schirmann et al. (2013) to those in the current study with respect to rumination time is even more remarkable as the 2 investigations were done in different countries with different cows under different farm conditions and with different sensor types.

The onset of rumination activity postpartum occurred quite late: cows started their first rumination period on average 355 min after calving. Cows and calves were separated 1.5 to 2 h postpartum at the latest. The presence of the calf and thereby cow-calf interaction might have had a considerable effect on the resumption of rumination. Nevertheless, the low rumination activity continued several hours beyond removal of the calf. A rapid recovery of feed intake after calving is desired to reduce potential disadvantages in the subsequent lactation (Mainau and Manteca, 2011). Feeding time was lowest in the first hour after calving but increased from the second hour postpartum in investigations by Jensen (2012). The onset of rumination activity is expected in general with a slight delay in feed intake. Delays in resuming rumination or discrepancies in the extent of rumination activity from the expected one are an alert signal and might be related to disturbed feed intake or health disorders.

CONCLUSIONS

In this study, we evaluated rumination characteristics (rumination time, number of rumination jaw movements, number of boli, number of boli per rumination minute, number of rumination jaw movements per rumination minute, and length of rumination periods and breaks) around parturition. Cows stopped ruminating on average 2 h before and resumed ruminating approximately 6 h after calving. Hence, for most investigated cows, rumination time was clearly reduced in the hours around parturition; therefore, short-term analysis of rumination time in 2-h units is useful for prediction of calving. In addition, the duration of rumination periods and breaks directly before and after parturition tended to differ from those before and after, although they varied largely among individual cows. Rumination characteristics at a temporal resolution of 1 min around parturition have rarely been described in the literature and their informative value for calving and health monitoring should be clarified by using a wider database. Further rumination characteristics, such as boli per rumination minute and rumination jaw movement per rumination minute, did not change as widely as rumination time and are considered less suitable for detection of calving events.

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