Interpretation of data from GPS-collars with movement sensors on cattle

Tolkning av data från GPS-halsband med rörelsesensorer på nötkreatur

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Index

Abstract

In this study GPS-collars with movement sensors were used on Nelore heifers on relatively small pastures in southern Brazil. Visual observations of the collared animals were made, so that data on the animal's actual behaviour could be compared to the data from the collars. The aim of the study was to verify and discuss the information about cattle behaviour provided by the GPS-collars and the movement sensors in them.

No conciderable difference between the counts from the left/right and the forward/backward movement sensors could be detected. Hence the sum of the data from both of the movement sensors was used. Different behaviours and combinations of behaviours were tested for correlation to the sum of the movement data, and to distance traveled between the GPS-locations. It was not possible to determine if the animals were ruminating or not. High counts in the sum of the activity data from the movement sensors with some certainity indicated 'Grazing', and low counts in the movement sensor data indicated resting. It was not possible to determine from this study if longer distances traveled between the GPS-locations meant walking, but that is likely the case.

The main conclusion from this study is the clear connection between observed grazing and walking behaviour on one hand and the collars recorded activity in movement sensors and distance between GPS-locations on the other. Also, the relationship between the collars data and observed lying and standing are clear as long as the animals are not ruminating.

Sammanfattning

I denna studie användes GPS-halsband med rörelsesensorer på kvigor av rasen Nelore på relativt små beten i södra Brasilien. Visuella beteendeobservationer av de djur som bar halsbanden gjordes, så att data som visade djurens beteende kunde jämföras med data från halsbanden. Syftet med studien var att verifiera och diskutera den information om nötkreaturs beteenden som erhålls med hjälp av GPS-halsbanden och rörelsesensorerna i dessa.

Ingen stor skillnad kunde urskiljas mellan summorna av aktivieten som uppmättes i vänster/höger- och frammåt/bakåt-rörelsesensorerna. Därför användes summan av datan från de båda rörelsesensorerna. Olika beteenden och kombinationer av beteenden jämfördes med summan av datan från vänster/höger- och frammåt/bakåt-rörelsesensorerna, och med grafen över tillryggalagd sträcka mellan GPS-punkterna. Det var inte möjligt att avgöra om djuren idisslade eller inte. Höga värden på suman av aktivitetsdatan från rörelsesensorena indikerade ganska säkert att djuret betade, och låga värden på summan av datan från rörelsesensorerna indikerade vila. Det var inte möjligt att med hjälp av den här studien avgöra om längre tillryggalagd sträcka mellan GPS-punkterna betyder att djuret går eller vandrar, men detta är troligt.

Den huvudsakliga slutsatsen i denna studie är det klara sambandet mellan de observerade beteendena beta och gå å ena sidan, och halsbandens registrerade aktivitet i rörelsesensorerna och avstånd mellan GPS-punkterna å andra sidan. Dessutom är sambandet mellan halsbandens data och de observerade beteendena ligga och stå klart, så länge djuren inte idisslar.

Background

Behaviour and diurnal rhythm of cattle

Cattle are adapted to living on plains. Their natural behaviour is known from studies of wild relatives, such as American and European bison, and from studies of domesticated cattle that are practically feral (Jensen, 1983), such as the cattle of Donana National Park in Spain (Lazo, 1995). The home ranges of free living cattle are often very large, and include grazing areas, resting areas and water holes (Jensen, 1983). According to Howery *et al.* (1996), numerous studies show that cattle use some areas more than others. When the heard travels between different parts of the home range they use established paths, which traverse the home range and help the herd to find their ways within the area (Jensen, 1983).

Cattle are distinctive heard animals (Bouissou *et al.* 2001). This means that the behaviour of an individual is largely dependent on the behaviour of the rest of the heard. Therefore large parts of the heard usually perform the same activity (Jensen, 1983).

The cattle’s resting areas are often located near paths, to enable the heard to easily travel to other parts of the home range. They are also often located higher than the surrounding area, so that the animals get a good overview and can detect approaching threats in time. Cattle sleep in very short periods spread over both day and night (Jensen, 1983).

The diurnal rhythm varies a lot between different cattle breeds and environmental conditions. This is due to different breeds having adapted to different climates, and in some cases differences in the digestive system between different breeds (Jensen, 1983). Lactating and non-lactating cattle have different diurnal rhythms (Kilgour & Dalton, 1984). The diurnal rhythm is also affected by the weather. Bad weather reduces the grazing time (Jensen, 1983). Cattle graze mainly in three or four periods every day (Jensen, 1983; Kilgour & Dalton, 1984). Sometimes grazing also occurs at night. Ruminating takes about 4 to 9 hours out of 24, and is spread over about 15 – 20 periods. The animals lie down for about 60 – 80% of the ruminating time (Jensen, 1983).

Reasons to study animal landscape use

What parts of the landscape animals use is affected by several environmental and animal factors, such as vegetation, distance to water, salt and minerals, species and breed of animal, and knowledge of the area (Ganskopp, 2001). By studying which behaviour animals perform in different parts of the landscape it can be determined how animals use different habitats. Studying behavior in conjunction with habitat selection may help determine if habitats provide different resources (Graham, 2001). Cattle may for example, as mentioned above, use one habitat for grazing and another for resting (Jensen, 1983).

It can be important for animal welfare to know what parts of the landscape the animals need to use to perform their natural behaviour, and what parts they often use, to be able to design appropriate housing systems and pastures (Wechsler, 2007). It can also be important for scientific purposes to quantify activities and travels of animals exposed to differing treatments (Ganskopp, 2001; Schauer *et al.* 2003).

In order to be able to protect areas for conservation purposes, knowledge about what areas animals use is needed. (Klar *et al.* 2008; Harris *et al.* 2008) Also to be able to manage these protected areas, understanding of the interactions among certain animals and other components of their ecosystem is needed (Detling, 1998). According to Barbari *et al.*

(2006) one of the main objectives of ecologists and experts in landscape planning is to understand what influences the animal’s movements and distribution over the land. This makes it possible to manage both wild and domestic animal populations in order to satisfy both conservationists and productive aims (Barbari *et al.* 2006).

In large herbivores, such as cattle, the greatest impact they have on the landscape is the removal of grass It is therefore important to determine where and for how long the animals graze. Other interesting activities for studying might be travelling (walking without grazing) and resting (Ungar *et al.* 2005).

Methods to study animal landscape use

To be able to study the landscape use by animals, a good record of the location of individuals over time is required. Tracking animals with Global Positioning System, GPS, represents a major advance in acquisition of these data. The collar registers the animal’s location with predetermined intervals, and a series of GPS-locations over time is obtained (Ungar *et al.* 2005).

Many species of wild and domestic animals have been fitted with GPS-collars since the technique became available. Some examples are zebras (Brooks *et al.* 2007), maned wolves (De Melo *et al.* 2007), moose (Moen *et al.* 1996), bears (Gervasi *et al.* 2006, Heard *et al.* 2008), sheep (Hulbert *et al.* 1998) and cattle (Barbari *et al.* 2006, Ganskopp, 2001, Ungar *et al.* 2005). By using Geographical Information Systems, GIS, together with the GPS collars animal distribution and movements can be related to landscape features (Ungar *et al.* 2005).

Conclusions about the foraging ecology of animals can be made by pairing data concerning the animal’s location with associated data on animal activity (Graham, 2001). In principle, it is possible to determine cattle activity from the distances between the successive GPS-locations. Since the GPS-locations are recorded with steady time intervals, short distances between two locations would mean the animal is resting, medium distances would mean grazing, and long distances would mean travelling. However this method may be less reliable than expected, since there is a certain level of error in the GPS-locations, and the cattle can change activities several times between two recordings (Ungar *et al.* 2005). Also the distance trevelled is likely to be underestimated because straight-line pathways are assumed between successive coordinates (Schauer *et al.* 2005).

There are GPS-collars that are also equipped with head forward/backward and left/right movement sensors (Schauer *et al.* 2005, Ungar et al 2005). These record movements over a specified time period, and therefore indicate activity. According to Ungar *et al.* (2005) the integration of movement sensors and accurate position data from GPS-collars provide the best method available today for determinations of animal activity and resource use in remote environments. However, to interpret data from the movement sensors, and discriminate between different activities, visual observations of collared individuals are required (Ungar *et al.* 2005).

Aim and questions for this study

The aim of this study is to confirm and discuss the information about cattle behaviour obtained from GPS-collars and the movement sensors in them by comparing them with data from direct observations. By trying to interpret activity data from GPS-collared Nelore heifers on relatively small pastures in southern Brazil, and comparing it to data from visual observations of the collared animals, the following questions will be answered:

- Do higher or lower counts in the left/right or the forward/backward movement sensors indicate certain behaviours?
- Can the data from the movement sensors and the distances traveled between the GPS-locations show whether the cattle are grazing, resting or travelling?
- Is it possible to see in the activity data whether the animal is ruminating or not?

Matherials and methods

The study was performed on heifers of the breed Nelore at the campus of the São Paulo State University, Universidade Estadual Paulista “Julio de Mesquita Filho”, UNESP, in Jaboticabal, southern Brazil. The cattle at the campus were kept at a large field divided into many pastures of about one hectare each. On every pasture a group of six to eight animals was kept. The animals in each group had free access to water in vats most often located towards the middle of the pasture. The animals also had access to mineral feed in a container, and the mineral feed was replenished once every day or every other day. The pastures were rather flat, with no trees or bushes, but only grass. The weather during the period of the study was mostly sunny with temperatures at mid day around 30^{o}C.

GPS-collars

Three GPS-collars (GPSPlus2 Vectronic Aerospace GmbH, Berlin) were used. They were placed on three heifers on the same pasture for about a week, and then moved to three other heifers on another pasture for the next week, and this was repeated for seven groups of heifers. The collars registered a GPS-location every fifth minute, and also contained movement sensors that registered head left/right (hereafter called X) and forward/backward (hereafter called Y) movement, so that the animal’s activity could be measured.

Visual observations

Visual observations of the collared animals were performed on two groups of heifers. Each group consisted of seven heifers, and three heifers in each group had a GPS-collar on. Only the heifers with collars were observed. The animals were marked with numbers at the upper shoulder and thigh on both sides. The first group was studied for five days, from the 19th to the 23rd of March 2008, and the second group for three days, from the 25th to the 27th of March 2008. The studying was performed for ten hours each day, between 08.00 and 18.00. At some occasions the studies had to be interrupted for a few hours because of rain or an observer’s absence.

Instantaneous scan sampling (Lehner, 1996) was used. Observations of all three collared animals were made once every two minutes. The behaviours recorded were ‘Grazing’, ‘Standing’, ‘Standing Ruminating’, ‘Lying’, ‘Lying Ruminating’, ‘Walking’, ‘Drinking’, ‘Feeding Minerals’, ‘Grooming’ and ‘Other behaviour/Missed observation’. The behavioural definitions used are listed in appendix 1.

Analysis of data

All data, from the GPS-collars (GPS-locations and data from the movement sensors) and from the visual observations, were compiled in Microsoft Excel and thereafter analysed in Minitab 15. The first observation hour of the day, containing observations from 08.00 to 08.59 was titled hour 8. The next hour, from 09.00 to 09.59 was titled hour 9 and so on, up to hour 17.

Collar data

Only data from the eight days, and the 10 hours each day, when the visual observations were performed was used. For each hour a mean value of activity in the X and Y movement sensors and distance traveled between GPS-locations over the eight days was calculated. This was related to the mean of all the hours.

Visual observation data

For each hour, a mean value of observations of each behaviour over all the nine observation days was calculated. The data from all hours with more than ten observations missing were removed before the analysis, because any behaviours observed in these hours would represent an unnormally large percent of the total amount of observations performed that hour. For each behaviour, the mean of each hour was then expressed in relation to the mean of all hours.

Data on different behaviours and combinations of behaviours were compared to activity data from the GPS-collars. Correlations between the frequency of behaviours and the amount of activity in the movement sensors and distance traveled were tested with a Pearson correlation test.

Results

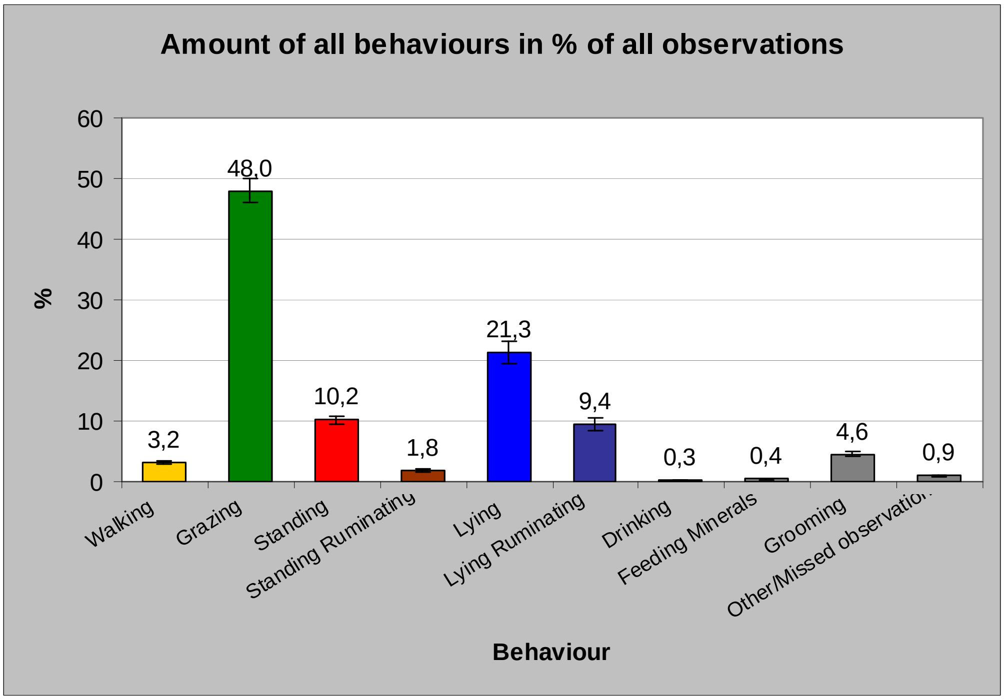

Figure 1: The amount of all behaviours, with Standard Errors, in percent of all observations.

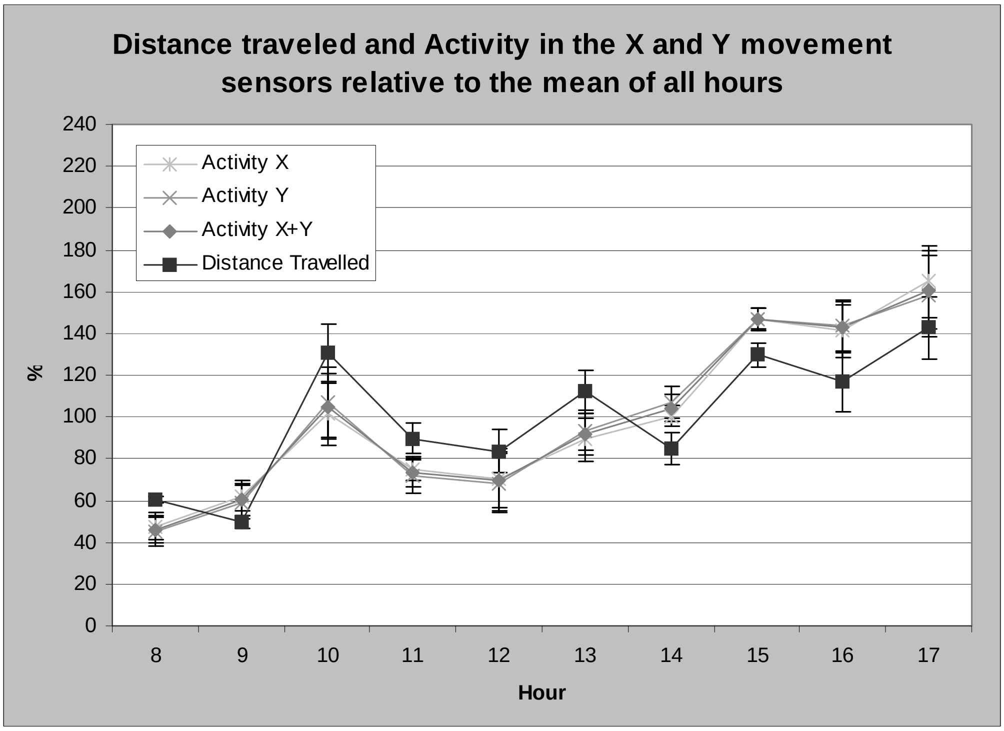

Figure 2: The mean distance traveled between GPS-locations and the mean percent of activity recorded in the X and Y movement sensors for the hours when the visual observations went on, relative to the mean of all the hours. Mean ± SE.

As seen in Figure 1, the cattle's main activities during the day is grazing and resting in some form. 'Walking' accounts for 3.2 % of the observations, and 'Grazing' for 48.0 %. 'Standing', 'Standing Ruminating', 'Lying' and 'Lying Ruminating', which together can be defined as resting behaviours, accounts for 42.6 % of the observations. The behaviours 'Drinking', 'Feedning minerals', 'Grooming' and 'Other/missed observation' together account for only 6.2 % of the observations.

The activity recorded in the X movement sensor relative to the mean of all hours, and the activity recorded in the Y movement sensor relative to the mean of all hours, as seen in Figure 2, are not significantly different from each other. They are also not considerably different from the sum of the activity data from them both relative to the mean of all hours. This means that the X movement sensor and the Y movement sensor did not record very different data, and no behaviour caused a lot more movement in one of them than in the other one. For comparing to different behaviours the sum of the X and Y movement sensor data was therefore used. The graph displaying the 'Distance traveled' does not follow the ones displaying the data from the movement sensors. This indicates that the information on distance traveled gives a different measurement on activity from the data obtained from the movement sensors.

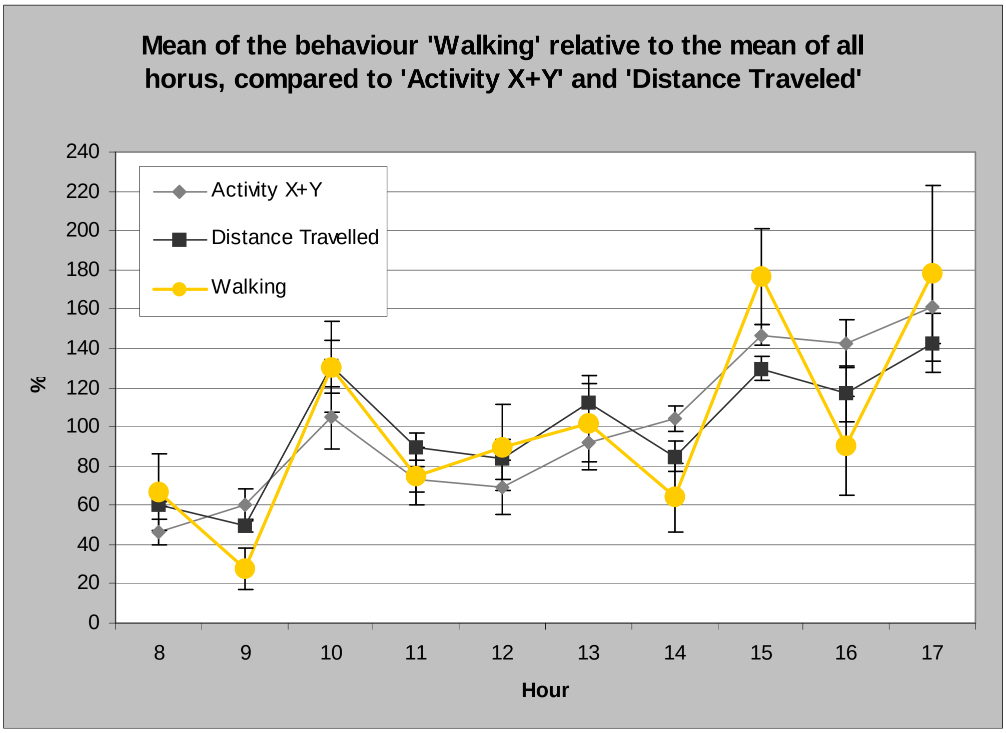

Figure 3: The mean frequency of the behaviour 'Walking' over all the hours the visual observing of the animals went on relative to the mean of all hours, compared to the activity registered by the movement sensors and the distance traveled between the GPS-locations. Mean ± SE.

The graph displaying the amount of walking, in Figure 3, correlates strongly to the one with distance traveled (correlation coefficient 0.901, $P < 0.001$). It is less correlated to the one with X + Y movement activity (correlation coefficient 0.785, $P < 0.007$).

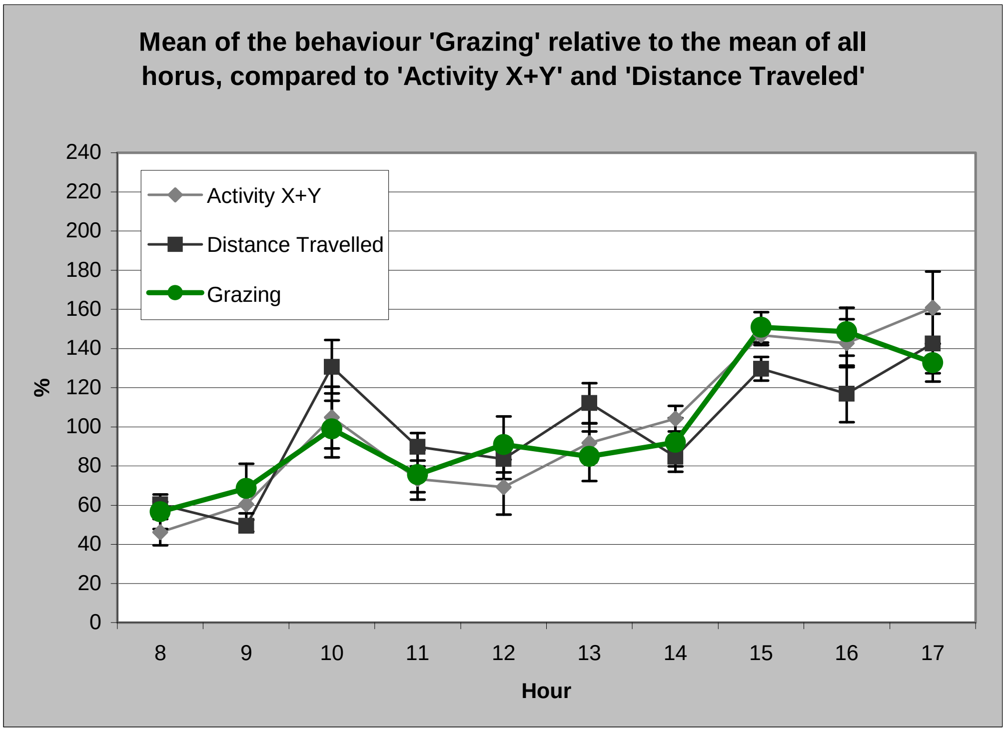

Figure 4: The mean frequency of the behaviour 'Grazing' over all the hours the visual observing of the animals went on, relative to the mean of all hours, compared to the activity registered by the movement sensors and the distance traveled between the GPS-locations. Mean ± SE.

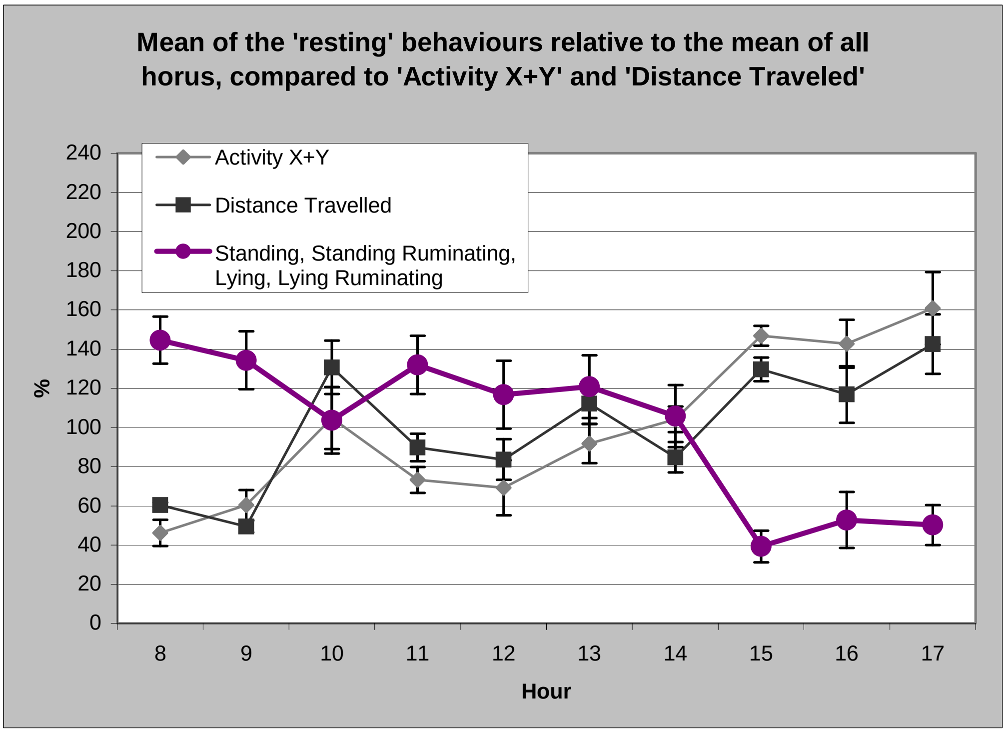

Figure 5: The mean frequency of the behavious 'Standing', 'Standing Ruminating', 'Lying' and 'Lying Ruminating' over all the hours the visual observing of the animals went on, compared to the activity registered by the movement sensors and the distance traveled between the GPS-locations. Mean ± SE.

The graph in Figure 4, displaying the amount of grazing correlates strongly to the one with X + Y movement sensor activity (correlation coefficient 0.942, $P < 0.001$). It correlates less to the one with distance traveled between the GPS-locations (correlation coefficient 0.787, $P < 0.007$).

The behaviours where the animal is relatively still, shown in Figure 5, can be defined together as 'resting'. The graph displaying the resting behaviors is strongly negatively correlated to the graph displaying the sum of X and Y activity (correlation coefficient -0.963, $P < 0.001$). It is less negatively correlated to the graph displaying distance traveled (correlation coefficient -0.789, $P < 0.007$).

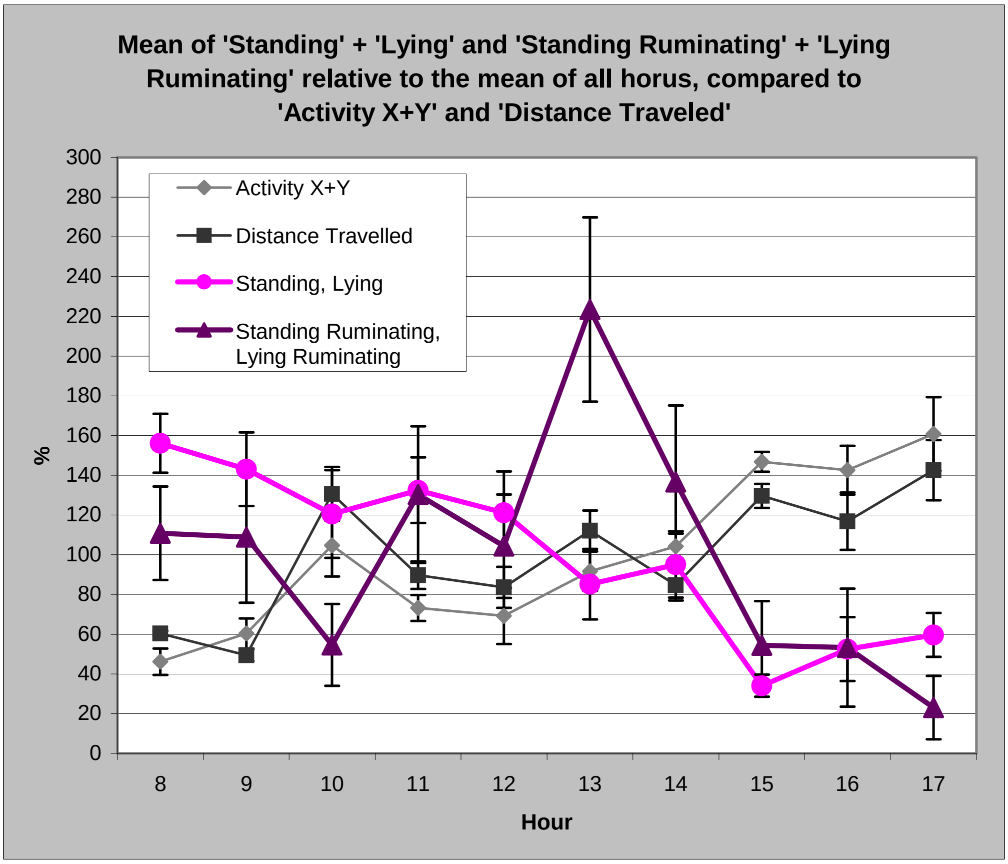

Figure 6: The mean frequency of the behaviours 'Standing Ruminating' and 'Lying Ruminating' relative to the mean of all hours, compared to 'Standing' and 'Lying' relative to the mean of all hours, and also compared to the activity registered by the movement sensors and the distance traveled between the GPS-locations. Mean ± SE.

The graph in Figure 6, displaying the amount of 'Standing' and 'Lying' is negatively correlated the X + Y activity (correlation coefficient 0.929, $P < 0.001$). The graph displaying the amount of 'Standing Ruminating' and 'Lying Ruminating', is negatively correlated to the X + Y activity (correlation coefficient -0.576). This correlation is however not significant ($P = 0.082$).

Discussion

Studies by Ganskopp (2001) and Ungar *et al.* (2005) compared data on distances between GPS-locations, data from movement sensors and data from visual observations. They showed that data on the distances between GPS-locations alone is not sufficient for predicting the cattle's activities. Ungar *et al.* (2005) found that movement sensor data greatly improved predictive abilities for grazing, resting and travelling.

The fact that 'Walking' in this study only accounts for 3,2 % of the observations might be due to the fact that the pastures in this study were rather small, and the animals therefore did not travel very far between different activities. Since the visual observations were only made once every second minute, the short walks might very well have occured between the observations. This is also the case with other 'short' behaviours, like 'Drinking', 'Feeding Minerals' and Grooming.

'Grazing' and resting ('Standing', 'Standing Ruminating', 'Lying' and 'Lying Ruminating') are the main activities during the day, and might be the most interesting behaviours to try to separate from each other when comparing to the collar data. These were also the most performed activities by cattle in the study made by Ungar *et al.* (2005).

Since there is no great difference in the amount of activity recorded in the X and the Y movement sensors in this study, probably no behaviours generated high counts in one of them without also doing so in the other. This means none of them has a connection to any specific behaviour more than the other. For example, in the study made by Ungar *et al.* (2005), refered to earlier in this paper, a low count on the left/right sensor and a high count in the forward/backward sensor indicated resting. No such conclusions can be drawn in this study. It might have been interesting to use some other types of movement sensors, to see if it is possible to separate behaviours more.

The sum of the activity data from the X and Y movement sensors however, is very useful in this study. The graph differs from the one displaying the distance traveled between the GPS-locations, and that means different behaviours are correlated more to either the 'Activity X + Y' or to the 'Distance traveled'.

Walking

A high count on distance traveled between GPS-locations would be expected if the animal walked for long distances, for example form resting areas to grazing or drinking areas. The 'Distance traveled' in this study is relatively constant over all the hours of the day. The fact that the mean amount of walking in different hours displayed in Figure 3 varies is probably due to that there were so few observations of walking in total. This of course, as mentioned above, is because the pastures were small and no longer periods or distances of walking was necessary for the cattle to travel between different parts of the pastures. In this study the graph over the amount of 'Walking' correlated well to the one with 'Distance traveled', but to investigate and test this connection further, a study performed on larger pastures would be necessary. Ungar *et al.* (2005) made studies on larger pastures, and found that large values on traveled distance were almost certainly associated with travelling. 'Walking' in this study was also quite stronglycorrelated to the activity recorded in the movement sensors. Ungar *et al.* (2005) reported that counts from both left-right and fore-aft movement sensors were weakly correlated to traveling, but also that the same range of movement sensor counts occurred when there was no traveling.

Grazing

‘Grazing’ correlated well to the activity data from the movement sensors, and this indicates that a high count from the movement sensors would mean that the animal is grazing. No other behaviour than ‘Grazing’ causes the counts from the movement sensors to rise that much. Grazing is also correlated to the data on distance traveled between GPS-locations. This seems natural, as cattle move slowly when they graze. Ungar *et al.* (2005) concluded that grazing in their study appeared to be most clearly related to the count from the left-right movement sensor. They also calculated mean distances traveled between GPS-locations for traveling, grazing and resting, but their study was made on larger pastures. Such conclusions can not be drawn from this study, since there is not much traveling required on a small pasture. Again maybe a different type of movement sensors, or some other device to measure certain activities might add interesting data that helps differing between behaviours.

Resting behaviours

Ungar *et al.* (2005) found that a low count on the left/right movement sensor in combination with a low traveled distance, or a low count on the left/right sensor and a high count in the forward/backward sensor almost certainly indicated resting. In this study the graph displaying the resting behaviours is strongly negatively correlated to the activity in the X and Y movement sensors. This can probably be explained by the fact that the opposite of these behaviours is almost only ‘Grazing’, wich renders a high count on the ‘Activity X + Y’. The other behaviours occur in such small extent they hardly influence this fact. Also Ungar *et al.* (2005) also reports that the response in the left-right movement sensor from resting was inverse to that of grazing. Resting however, as concluded by Ungar *et al.* (2005), is not always associated with very low movement sensor counts. Probable reasons for this is that comfort movements, such as grooming may be registered by the sensors (Ungar *et al.* 2005). Resting behaviours in this study are less strongly correlated to ‘Distance traveled’. This can at least to some extent be explained by the fact that the recorded distance traveled between GPS-locations never comes down to zero. The GPS-collars always record som meters wrong, and it thereby looks as the animal is moving a few meters even when it is absolutely still. Resting can therefore never be completely negatively correlated to ‘Distance travelled’.

Ruminating

The graph displaying ‘Standing’ and ‘Lying’, the resting behaviours without ruminating, is strongly negatively correlated to ‘Activity X + Y’, and that of course has the same explanation as regarding the other graphs over resting behaviours; it is the opposite of grazing. The fact that the graph displaying the ruminating behaviors (‘Standing Ruminating’ and ‘Lying Ruinating’) is less negatively correlated, and that this correlation is not significant, might mean that these behaviours rendered some activity in the movement sensors. However the total amount of ruminating behaviours observed is very small, and this probably explains the contingency in the results. No conclusions about whether the animals are ruminating or not can be drawn from the movement sensor data in this study. Some sort of device to measure chewing activity might have helped determine if the animals were ruminating or not, and would have been interesting to try out.

Conclusions

According to Ungar *et al.* (2005) the integration of movement sensors and accurate position data obtained from the GPS-collars provide the best method available for determining animal activity and resource use in remote environments. They conclude that grazing, traveling and resting behaviours of cattle can be inferred with reasonable accuracy from the data provided by the collars they used.

In this study no difference between the counts from the left/right (X) and the forward/backward (Y) movement sensors could be detected, and therefore difference between those could not indicate any certain behaviours. It was difficult to determine if the animals were ruminating or not. High counts in the 'Activity X + Y' combined with unchanged 'Distance traveled' with some certainity indicated 'Grazing', and since most of the time when the cattle were not grazing was spent resting, low counts in the 'Activity X + Y' indicated resting in some form. It was not possible to determine from this study if longer distances traveled between the GPS-locations meant walking, but that is likely the case.

The main conclusion from this study is the clear connection between observed grazing and walking behaviour on one hand and the collars recorded activity in movement sensors and distance between GPS-locations on the other. Also, the relationship between the collars data and observed lying and standing are clear as long as the animals are not ruminating.

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Appendix 1: Definitions of Behaviours

Grazing	The animal is standing or walking slowly and eating grass. The nose is below the tops of the grass.
Standing	The animal is standing still with the nose above the grass tops.
Standing ruminating	The animal is standing and ruminating.
Lying	The animal is lying on the ground and not ruminating. Also when ruminating is not visible.
Lying ruminating	The animal is lyingon the ground and ruminating.
Walking	The animal is walking with the nose above the grass tops.
Drinking	The animal is drinking from the water vat. The nose is below the edge of the vat.
Feeding minerals	The animal is eating mineral supplement from the container.
Grooming	The animal is grooming, licking or scratching itself or another animal. Also when the animal is actively taking part in being scratched or licked by another individual.
Other behaviour/ missed observation	The animal is performing a behaviour other than the ones above, or the animal is not visible. Also when the observer missed to make the observation on time.

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