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The influence of feeding opportunities of six zoohoused Giraffa *camelopardalis rothschild*

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Abstract

Previous studies on captive giraffes have shown that an increase in foraging opportunities leads to reduced abnormal behaviour. This study evaluates the nocturnal behaviours of six captive giraffes, housed in Aalborg Zoo (N: 57.04°, E: 9.90°). The herd consists of one male giraffe (age 8), one male calf (age 1 ½), two femelle giraffe (age 7; 20) and two female calves (age 8 months; 2 years). The observations lasted eight nights and compared two observation periods (October and November) with different compositions of branches. The giraffes spent approximately 30% of their nocturnal activity on feeding behaviour. An increase in feeding behaviour was correlated with a decrease in oral stereotypy. It was observed that the type of branches influenced time spent on browsing as it was consumed at different rates. Further studies are required to clarify questions left in this study, such as studies with more observation days and known types of branches. .

Keywords: Giraffa *camelopardalis rothschildi,* Nocturnal Behaviour, Zoo,Stereotypical Behaviour, Feeding, Enrichment, Ethology, Animal Welfare, Ruminants

الملخص

أظهرت الدراسات السابقة على الزرافات الأسيرة أن زيادة فرص البحث عن الطعام تؤدي إلى تقليل السلوك غير الطبيعي. تقيم هذه الدراسة السلوكيات الليلية لستة زرافات أسيرة في حديقة حيوانات البورج (شمالاً: 57.04 درجة شرقاً: 9.90 درجة).يتكون القطيع من ذكر زرافة (8 سنوات) وعجل زرافة ذكر (1 ½) واثنين من زرافة أنثى (7 و 20 سنة) وعجولان زرافة (عمران 8 شهور ، سنتان). استغرقت الملاحظات ثماني ليال وقارنت فترتين (أكتوبر ونوفمبر) بتركيبات مختلفة للفروع. قضت الزرافات ما يقرب من 30 ٪ من نشاطها الليلي على سلوك التغذية. ارتبطت زيادة في سلوك التغذية مع انخفاض في الصورة النمطية عن طريق الفم. لوحظ أن نوع الفروع أثر على الوقت الذي يقضيه في التصفح حيث تم استهلاكه بمعدلات مختلفة. هناك حاجة إلى مزيد من الدراسات لتوضيح الأسللة المتبقية في هذه الدراسة ، مثل الدراسات مع المزيد من أيام المراقبة وأنواع الفروع المعروفة.

الكلمات المفتاحية :زرافة كاميلوباردااليس روتشيلد ، السلوك الليلي ، حديقة الحيوان ، السلوك النمطي ، التغذية ، الإثراء ، علم السلوك ، رعاية الحيوان ، المجترات

Introduction

In recent years, many zoos have strived to improve conditions to ensure more species-specific behaviour of their animals. This includes the enlargement of enclosures and several alternative types of enrichment with the goal of improving welfare (Claxton, 2011). Bashaw et al. (2001) collected behavioural data from 257 giraffes housed at 71 different Northern-American zoos, in which as many as 80 % of the individuals showed stereotypical behaviour. Stereotypical behaviour is defined as abnormal behaviour

with “unvarying repetitive behaviour patterns that have no obvious goal or function in the context in which they are performed” and is considered an indicator of stress (Fernandez et al., 2008).

In the wild, giraffes (*Giraffa camelopardalis*) spend about 60-80 % of their activity budget on feeding and ruminating activity (Orban et al., 2016; Okabe et al., 2019). Their natural diet consists primarily of leaves, forbs and woody plants, but when their nutritional needs are not fulfilled, they will also consume grass (O’Connor et al., 2015; Munyaka & Gandiwa, 2018).

In captivity, the amount of browse may be limited due to practical and financial resources as especially browsers require a diet that is not readily available (Young, 1997; Hatt et al., 2005). It is recommended that 10-25 % of the diet consist of browse material for captive giraffes (Hatt et al., 2005).

Lack of natural environmental factors such as foraging facilities may result in abnormal behaviour and thereby a decrease in animal welfare (Young, 1997; Fernandez et al., 2008). For larger herbivores in captivity, abnormal behaviour is frequently expressed as oral stereotypy (Koene, 1999; Tarou et al., 2000). Oral stereotypy is often interpreted as a sign of stress; however, it has been hypothesised that it also serves to increase the flow of saliva to the rumen (Tarou et al., 2000; Bergeron et al., 2006). Feeds, such as grains, fresh fruit and vegetables, provide a smaller amount of chewing and results in rapid fermentation and lower pH (Grünberg et al., 2009; Gussek et al., 2017b). Fresh fruit and vegetables in giraffes’ diets may result in a higher flow of saliva to the rumen from oral stereotypies thereby causing rumen acidosis as a lower fibre intake result in a decrease in pH (Gussek et al., 2017b; Johansen, 2020). This, combined with the fact that giraffes usually spend around 60 % of their time browsing in the wild providing oral stimulation, could be the source of different observed oral stereotypies (Bashaw et al., 2001; Baxter & Plowman, 2001). This is further supported by Robert et al. (1993) which argued that oral stereotypy in animals is primarily caused by frustrated feeding motivation.

In a study including 12 German zoos, the type of forage was shown to influence the giraffe behaviour (Gussek et al., 2017a). A less energy-rich diet led to a higher level of foraging along with a decrease in oral stereotypy (Gussek et al., 2017a). This was further investigated by Monson et al. (2018) in which an experimental feed was given to six giraffes in Cleveland Metropark Zoo. The feed composition was changed from a 1:1 ratio between hay and grain *(Mazuri® Wild Herbivore Diet Hi-Fiber)* to a 9:1 ratio, along with added supplemental browsing material. This resulted in a reduction in the expression of oral stereotypy along with a decrease in salivary production (Monson et al., 2018). Hummel et al. (2006b) found, that during fermentation, browse material has the lowest gas production when compared to grass, herbs and legumes. On top of this, twig browse material also had the lowest nutritional value compared to grass, herbs, legumes, and leaf browse. These factors contribute to the idea that a diet including a sufficient amount of browse material, are the most beneficial for their digestion and tongue stimulation (Hummel et al., 2006b; Fernandez et al., 2008; Okabe et al., 2019).

It is generally important for captive giraffes that enough foraging opportunities are available as part of an attempt to achieve optimal living conditions (Young, 1997; Fernandez et al., 2008; Berthelsen et al., 2021). In wintertime, northern zoos (N: 52°) may have problems providing enough leaves for the browsing animals. Therefore, natural browsing opportunities cannot be supplied equally year-round.

The nocturnal behaviour of giraffes has not yet been thoroughly researched, leaving the amount of foraging during this time of day to be questioned (Rose & Croft, 2018).

The aim of this study was to evaluate how much time captive giraffes spend feeding at night and if the amount of leafy browsing material influenced giraffe behaviour. It was hypothesized that an increase in leafy matter will cause more time spent feeding and a decrease in the expression of oral stereotypy.

Materials and Methods

Subjects

This study examines the nightly behaviour of six giraffes (*G. camelopardalis rothschildi)* from Aalborg Zoo in Denmark using surveillance cameras. The herd consists of one bull (Giraffe B), one male calf

(Giraffe D), two cows (Giraffe C and Giraffe F) and two female calves (Giraffe M and Giraffe Q). One of the two cows was heavily pregnant (Giraffe F). The bull was born in Zoologischer Garten Magdeburg and transferred to Aalborg Zoo in 2015 while the remaining herd was born at Aalborg Zoo. The age range spanned from eight months to 20 years (Appendix A).

Enclosure

The observed indoor enclosure was around 146 m² and was divided by a fence into a larger and a smaller fold. The oldest bull (Giraffe B) occupied the smaller fold, while the others occupied the large fold. One plastic trough was hanging from the bars of the enclosure in the smaller fold, while the larger fold contained six plastic troughs at the front. These were out of sight for the camera due to the position in the upper corner at the front of the enclosure. Of the three hay racks, two of them hung from the ceiling, while the last one was mounted low on the wall so the younger giraffes could reach. One roof hay rack was accessible from the smaller fold and the other hung inside the larger. On each side of the room, branches were hung for browsing opportunities. Two drinking fountains were located inside the larger fold and one inside the smaller.

The giraffes were led inside between 14:00-16:00 and led outside at around 09:00-11:00 depending on the weather. In the outside enclosure, the giraffes had access to branches and hay though this was not observed. In the indoor enclosure, the light got turned off from 22:00 until 7:00, leaving the perceived night-time for the giraffes consistent at nine hours a day with zero natural light exposure during autumn nights.

Feeding

A mix of 1/3 browser ruminant cubes (Dodson&Horrell, Nantwich, Great Britain), 1/3 browser pellets (Kaspers FaunaFood, Woerden, Netherlands) and 1/3 Boscos (WESenterprises, Thabazimbi, South Africa) were given to the herd daily.

In the morning, prior to letting the giraffes out into the outdoor enclosure, half a bucket of the mix was given to the bull and one bucket for the rest of the herd. During the afternoon, before the giraffes were moved into the indoor enclosure, the bull was given ¾ of a bucket with concentrate while the rest of the herd were given two full buckets. In addition to the concentrate, each metal feeder was filled with alfalfa and thoroughly shaken. Each of the hanging feeders also received a bucket of extra leaves (Fodergrossisten, Hjørring, Denmark). The branches got changed in accordance with the observed need, with a preference for several branches in each hoist.

Data collection

The behaviour of the giraffes was taped with a permanently installed camera at Aalborg Zoo running 24 hours per day. The camera had night vision, which allowed the study to take place at night-time. The indoor camera covered the majority (>80 %) of the enclosure, except for blind angles behind objects and the front part of the enclosure. The filming of the giraffes took place from 17:00 to 07:00 on each of the researched days. The first observation period (OBS1) occurred from the 2nd of October 2021 to the 6th of October 2021, when leaves were still present on the branches. The second observation period study (OBS2) occurred from the 1st of November 2021 to the 5th of November 2021, when most branches were without leaves. The differences in the amount of branches with and without leaves in the observation periods were noted and assessed as estimates (Appendix B).

During a pilot study, an ethogram was adapted and modified after Seeber et al. (2012) for the analysis of the behaviours (Table 1).

Inspired by the work of Seeber et al. (2012)

The videos were viewed by six observers (the first six authors of this paper), equal to the number of giraffes in the enclosure. This method allowed each observer to observe a single giraffe throughout the process. To assure agreeability among the observers, the team split into three teams of two observers

for a pilot study performed on 29th of September 2021. These observers reviewed two giraffes each and compared their results.

Table 1. Ethogram with the description of the chosen behaviours.

Behaviour categories	Behaviour	Description
Individual behaviour	Standing Still (SS)	Stationary position without locomotive activity (min. 5 sec).
	Locomotion (LO)	Walking and running.
Feeding behaviour	Browsing (BR)	The ingestion of branches, bark and leaves.
	Hay Feeding (HF)	The ingestion of hay from the hay racks, ground or elsewhere.
Resting behaviour	Lying Down (LD)	Lying down. Other behaviour can take place at the same time.
	Paradoxal Sleep (PS)	Lying down and resting its head on the flank of a hind leg.
Stereotypy	Pacing (PA)	Performing occurring in a repeated locomotive activity in a pattern (ex. straight line or circle) between two locations – without purpose).
	Oral Stereotypy (OS)	Repetitive licking of objects/mane. Swinging/keeping the tongue outside the mouth for a long time.
Other	Out of Sight (OOS)	When the giraffe is out of sight and/or the behaviour is unidentifiable.

Statistical analysis

The R^2-value was calculated to evaluate the correlation between the observers for the start- and endpoints. Half of the observers have previously conducted similar studies of giraffe behaviour (Berthelsen et al., 2021).

Correlation values (R^2) ranging from 0.9 to 1.0 were achieved ($R^2 \geq 0.90$ was considered acceptable).

Cumulative graphs were constructed using "integral (running sum)" in Past for each behaviour in each study period. Subsequently, the data were processed with log(y) to reduce the scaling effect regarding the variance in the mean. This method was used to confirm the saturation of data and is not further mentioned.

Stacked bar charts were created to visualize the distribution of the activity budget (Figure 1).

As the data was not normal distributed, a pairwise non-parametric Mann-Whitney was used to test difference in median of behaviour between individuals. This further provided a way to describe the comparison between a given behaviour and the observation periods (Table 2, 3 & 4).

Spearman's rank test was conducted to analyse if the three behaviours *"hay feeding"*, "*browsing"* and *"oral stereotypy"* were correlated to each other. The test was performed pairwise: *"hay feeding"* versus "*browsing"*, *"hay feeding"* versus *"oral stereotypy"* and "*browsing"* versus *"oral stereotypy"*. Since the observers were only able to compare four days for each behaviour the p-value was ignored (Appendix C).

For statistical analysis the software *Past (ver. 4.03), www.socscistatistics.com* and RStudio (2021), was used.

Results

Activity time budgets

In all giraffes, *"browsing*" behaviour increased from observation period 1 to observation period 2 except for Giraffe D (Figure 1). In both observation periods, Giraffe B and C displayed more "*hay feeding*" than *"browsing*". All giraffes spent between 33.20% (Giraffe C) and 59.37% (Giraffe M) of their activity budget on "*lying down*". Resting behaviour made up between 35.66% (Giraffe C) and 60.73% (Giraffe M) of the giraffes' activity budget. "*Out of sight*" ranged between 0% (Giraffe B) and

22.28% (Giraffe C) but made up less than 10% of the activity budget for most giraffes (Figure 1, Appendix C).

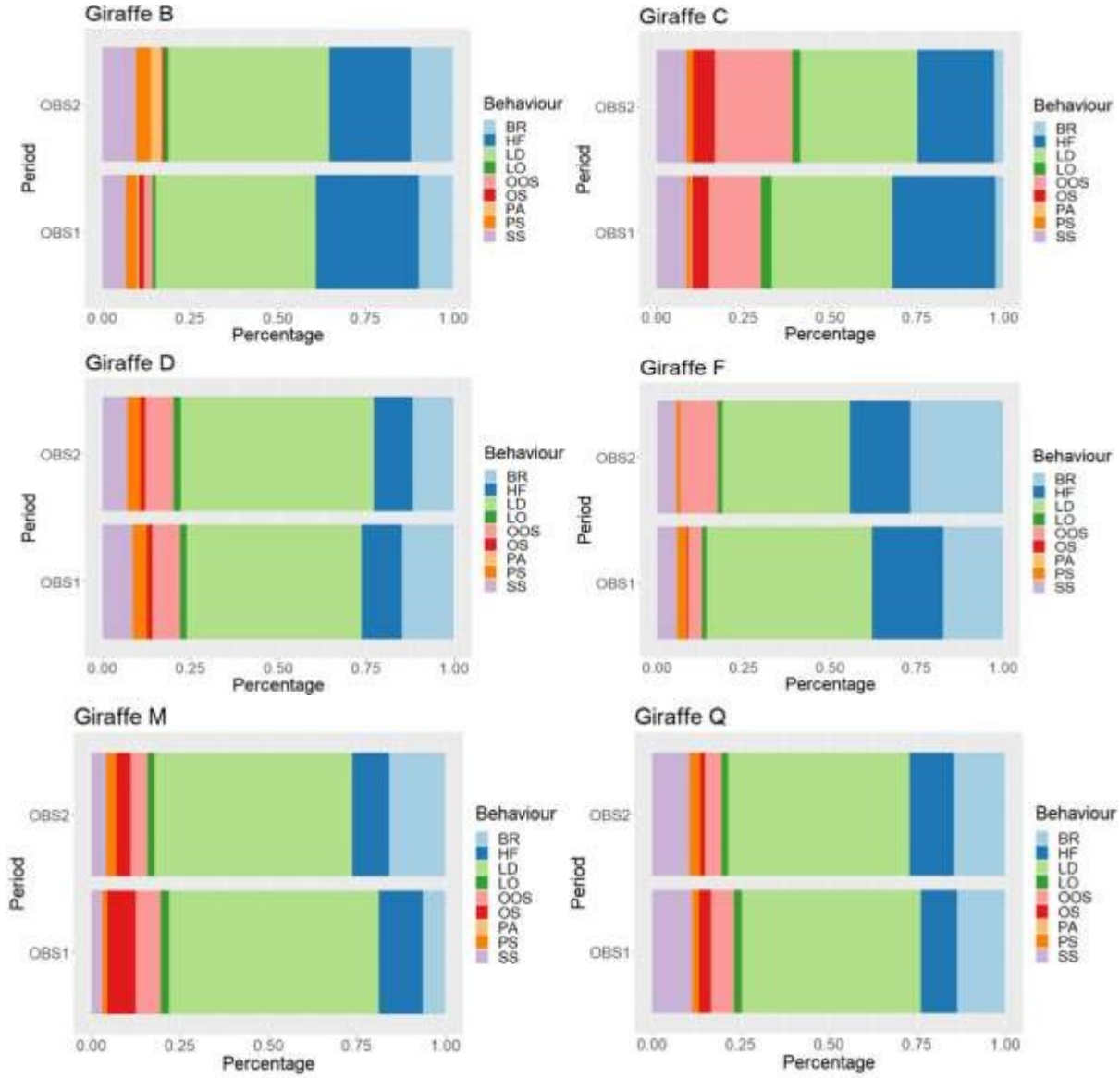

Figure 1. Stacked bar charts for each of the six giraffes. Along the x-axis, the percentage of each expressed behaviour is shown, while the y-axis shows the two observed periods (1 and 2). Light blue shows "browsing" (BR). Dark blue shows "hay feeding" (HF). Light green shows "lying down" (LD). Dark green shows "locomotion" (LO). Salmon shows "out of sight" (OOS). Red shows "oral *stereotypy" (OS). Light orange shows "pacing" (PA). Orange shows "paradoxal sleep" (PS). Light purple shows "standing still" (SS).*

Behavioural differences between observation periods

Medians for each individual's behaviour in the observation periods were compared with a pairwise Mann Whitney test (Table 2).

Comparing observation period 1 and 2 Giraffe B spent significantly ($p < 0.05$) less time on the behaviours *"hay feeding"* and *"locomotion"*. Giraffe C spent significantly ($p < 0.05$) less time during observation period 2 in the behaviours *"hay feeding"* and *"locomotion"*, while spending significantly

($p < 0.05$) more time on "*browsing"*, *"oral stereotypy"*, *"paradoxal sleep"* and "o*ut of sight*". During observation period 2, Giraffe D spent significantly ($p < 0.05$) more time on *"locomotion"*. For Giraffe F, a significantly ($p < 0.05$) longer amount of time was spent on "*browsing"* while significantly less time was spent on *"locomotion"*.

Giraffe M spent significantly ($p < 0.05$) less time during observation period 2 on the behaviours "*locomotion*" and "*lying down*", while spending significantly ($p < 0.05$) more time on "*browsing*". Lastly, Giraffe C spent significantly ($p < 0.05$) less time on "*standing still*" during observation period 2 (Table 2).

Table 2. P-values for comparing the frequency of different behaviours (medians of observation period 1 versus observation period 2) using Mann-Whitney for the nine different behaviours.

OBS1 vs. OBS2	Giraffe B	Giraffe C	Giraffe D	Giraffe F	Giraffe M	Giraffe Q
Hay Feeding	3.028E-06	0.0175	0.206	0.987	0.577	0.827
Browsing	0.769	0.00175	0.665	0.0164	0.0300	0.644
Locomotion	0.0398	0.0419	0.0038	0.000155	0.0170	0.791
Standing Still	0.196	0.0720	0.215	0.0628	0.114	0.000703
Oral Stereotypy	0.511	1.826E-07	0.421	0.253	0.928	0.510
Pacing	0.511	0.00114	—	—	—	—
Lying Down	0.823	0.971	0.0835	0.155	0.0428	0.503
Paradoxal Sleep	0.206	0.0499	0.665	0.365	0.887	0.521
Out Of Sight	—	2.531E-09	0.234	0.368	0.878	0.329

Significant p-values ($p < 0.05$) are marked with bold. Behaviours with a lack of data and therefore unable to compute the test are marked with -.

Behaviour correlations

A negative correlation was found between "*hay feeding*" and "*oral stereotypy*" during observation period 1 for three out of six giraffes. Giraffe F showed a strong positive correlation between these two behaviours (table 3). During observation period 2, a negative correlation was found between behaviours "*hay feeding*" and "*oral stereotypy*" for three giraffes. Positive correlations were found for giraffes Q and F (table 4).

Table 3. Calculated spearman's correlation when comparing "hay feeding" (HF) versus "browsing" (BR), "hay feeding" (HF) versus "oral stereotypy" (OS) and "browsing" (BR) versus "oral stereotypy" (OS) during observation period 1 (OBS1).

	HF OBS1 vs. OS OBS1	BR OBS1 vs. OS OBS1
Giraffe B	-0.2	0.2
Giraffe C	-0.2	1
Giraffe D	*-0.4*	-0.2
Giraffe F	0.8	-0.8
Giraffe M	*-0.4*	*-0.4*
Giraffe Q	*-0.4*	-0.8

An association is marked with cursive and a high association with bold text for each giraffe.

Negative correlations between "*browsing*" and "*oral stereotypy*" during observation period 1 were found for three giraffes, whereas a strong positive correlation was found for Giraffe C (table 3). For observation period 2, negative correlations were found for three giraffes. A weak positive correlation was found for Giraffe Q while a strong positive correlation was found for Giraffe C (table 4).

Table 4. Calculated spearman's correlation when comparing "hay feeding" (HF) versus "browsing" (BR), "hay feeding" (HF) versus "oral stereotypy" (OS) and "browsing" (BR) versus "oral stereotypy" (OS) during observation period 2 (OBS2).

	HF OBS2 vs. OS OBS2	**BR OBS2 vs. OS OBS2**
Giraffe B	-0.8	0.2
Giraffe C	0.2	0.8
Giraffe D	*-0.4*	*-0.4*
Giraffe F	0.949	-0.949
Giraffe M	*-0.4*	-0.8
Giraffe Q	0.4	0.4

An association is marked with cursive and a high association with bold text for each giraffe.

Discussion

The impact of change in leafy matter

Five out of six giraffes showed an increase in the expression of "*browsing*" behaviour from observation period 1 to observation period 2 (Figure 1). For giraffes C, F and M, these changes were significant ($p < 0.05$) (Table 2). Hence, an increase in leafy matter did not correlate with an increase in "*browsing*" behaviour. It was noted that willow was consumed at a faster rate than other types of branches in this study (Appendix B). There was still bark left on the branches 07:00:00 most mornings during observation period 1, and thus no lack of browsing material (Appendix B). The type of branches given to the giraffes may influence browsing activity. Shorter browsing periods have been found to decrease oral stimulation, and thus increase oral stereotypy (Monson et al., 2018). Different branches in the browsing feed for giraffes may prolong browsing periods. Hawthorne has been found to increase the browsing time when compared to willow and cherry branches, which in turn led to a reduced expression of oral stereotypy (Monson et al., 2018; Okabe et al. 2019). Branches without leaves will be more dominated by fibres (Ngaha et al., 2016; Gussek et al., 2017b). As a previous study has found, a high fibre diet can be beneficial to the welfare of giraffes, as the high fibre intake leads to a prolonged rumination and therefore less time to perform oral stereotypies (Baxter & Plowman, 2001; Schüßler & Greven, 2017). This corresponds with the observation of the quantity of bark left on the browsing material during the two observation periods since there was less bark left in observation period 2 (Appendix B). Therefore, it would be beneficial for giraffes to have access to additional branches rich in fibre during colder season, as branches with a sufficient amount of leaves will not be available. Another possibility is conservation of willow by ensiling it, giving the opportunity of use all year round (Sauer, 2015; Duggan et al., 2015).

Previous studies have found a connection between proximity to winter and increased *"oral stereotypy"*, but this study found *"oral stereotypy"* to decrease from observation period 1 to observation period 2 (Okabe et al., 2019). An explanation for the decrease could be the fact that the giraffes were fed primarily willow during observation period 1, while the branches were unidentifiable during observation period 2.

Despite the fact that decreases in *"oral stereotypy"* were not significant ($p > 0.05$) for the giraffes, the time spent on *"oral stereotypy"* decreased from observation period 1 to observation period 2 in four giraffes (Table 2; Figure 1). This connection between an increase in "*browsing*" and a decrease in *"oral stereotypy"* is supported by Spearman's correlation, where a negative correlation ($r_s < -0.3$) was found in half of the giraffes in both observation period 1 and 2 (Appendix C). In general, there is a correlation between time spent on feeding and time spent on *"oral stereotypy"*, since the time spent on *"oral stereotypy"* decreases as time spent on feeding increases (Bashaw et al., 2001; Baxter & Plowman, 2001; Facey, 2017; Duggan et al., 2015). This correlation is supported by other studies, wherein a connection between overall feeding-related behaviour and decreases in stereotypies was found (Wagman et al. 2018; Fangmeier et al. 2019).

Only Giraffe C experienced a significant ($p < 0.05$) increase in *"oral stereotypy"*, despite also having a significant increase in *"browsing"*. This is further supported by a strong positive correlation for *"browsing*" and *"oral stereotypy"* in both observation period 1 ($r_s = 1$) and 2 ($r_s = 0.8$). A possible explanation could be unidentified sub-optimal conditions unrelated to browsing opportunities, which could cause *"oral stereotypy"* (Veasey et al., 1995). Furthermore, Giraffe C is the oldest giraffe in the herd and had a high level of *"oral stereotypy"* during both observation periods. No big impact on Giraffe C's oral stereotypy was expected, as stereotypical behaviours are thought to become more entrenched as animals get older (Mason, 1991).

Additional observations

It was observed that the hay rack in the corner of the enclosure, which was the only one available for the three calves, was emptied ~3.8 hours (SD ± ~2.28 hours) after 17:00 leaving the calves to spend most of the night without opportunity to express optimal feeding behaviour. Only a few data points of "*oral stereotypy*" were collected for giraffes D and Q while they still have access. Therefore, most recorded entries of *"oral stereotypy"* were observed after the primary opportunity for "*hay feeding*" ran out. A correlation between an insufficient amount of roughage intake and increased oral activity has been found (Hummel et al., 2006a). To the calves' needs for more hay, additional or a larger hay rack could be introduced into the enclosure. It might be beneficial to add a large plate under the hay rack to catch falling hay, that would otherwise end up as waste on the floor. This would also minimize clean-up for the zookeepers.

During the two observation periods, the average time consumption of *"paradoxal sleep"* (2.35%-2.65%) and *"feeding"* (29.61%-30.11%) which correlates with the nocturnal behaviour study by Burger et al. (2021) who found 2% and 27%, respectively. Notably less time spent on *"locomotion"* and *"standing still"* in this study when compared Burger et al. (2021) in which 39 individual Rothschilds giraffes were observed. However, those two behaviours were more equal to the time budgets for the reticulated giraffes examined by Burger et al. (2021). The observed differences are thought to be derived from age, environmental and social factors (Sicks, 2012; Appendix D).

Data reliability

Only a few behaviours did not reach data saturation due to the limited number of times the behaviour was observed. This was the case for behaviours such as *"paradoxal sleep"*, as the behaviour is highly continuous compared to *"hay feeding"*, that is more often interrupted.

Approximately 1.33 hours were missing from the total amount of ~112 hours (~1.2%) of videos. These were marked as "o*ut of sight*" as the observers were unable to observe the performed behaviour during this time.

While it would have been preferred to see every day continuously, electrical errors in the form of electrical shortage and failure to turn off the light at night made this impossible. This study argues these errors to be negligible, because ~112 hours of video were watched during the observation periods per giraffe, giving a total view count of ~672 hours for the entire study, which is more view time than several other behavioural studies (Bertelsen et al., 2020; Dahl et al., 2020; Olsen et al., 2020; Ottosen et al., 2020; Thomsen et al., 2020).

Conclusion

The nocturnal activity of six Rothschild giraffes in Aalborg Zoo showed that:

- The giraffes spend between 29.61 and 30.11 % of their night on feeding.
- An increase in feeding behaviour correspondingly reduced the time spent expressing stereotypic behaviours.

- Type of branches available to the giraffes had an influence on the expression of "*oral stereotypy"* and "*browsing*", presumably because different branch types were consumed at different rates.
- Further studies with more observation days across seasons with browsing material of known types of branches with and without leaves and measured quantities of browse would clarify many of the questions left in this study.

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Author's Contributions

E.M.E.E., K.M.-L., N.L., O.E.S.G., R.B.H. and S.E.J. did the investigation and data curation while E.M.E.E., K.M.-L., N.L., R.B.H. and S.E.J did the formal analysis and visualization and took the lead in writing the draft for the manuscript. Supplementary resources were provided by C.P. and T.H.J. All authors except O.E.S.G. provided feedback and contributed to the final version of the manuscript. C.P. and T.H.J. were responsible for the project. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

References

Bashaw M. J. Tarou L. R. Maki T. S. Maple T. L. 2001. A survey assessment of variables related to stereotypy in captive giraffe and okapi. *Applied Animal Behaviour Science* 73: 235-247. https://doi.org/10.1016/s0168-1591(01)00137-x

Baxter E. M. Plowman A. 2001. The Effect of Increasing Dietary Fibre on Feeding, Rumination and Oral Stereotypies in Captive Giraffes (*Giraffa Camelopardalis*). *Animal welfare* 10: 281-290.

Bergeron R. Badnell-Waters A. J. Lambton. S. Mason G. 2006. Stereotypic oral behaviour in captive ungulates: Foraging, diet and gastrointestinal function**.** *In Stereotypic Animal Behaviour: Fundamentals and Applications to Welfare 2nd Edition:* 19–57. https://doi.org/10.1079/9780851990040.0019

Bertelsen S. S. Sørensen A. S. Pertoldi C. Jensen T. H. Pagh S. 2020. Nocturnal behaviour of three zoo elephants (*Loxodonta africana*). *Genetics and Biodiversity Journal, Special issue (Behavioural Instability):* 92-113

Berthelsen A.K.L. Kjelgaard B.B. Møller-Lassesen K. Larsen N. Urup P. Jensen S. E. Pertoldi C. Alstrup A. K O. Jensen T. H. Pagh S. 2021. Behavioural instability as an indicator of personality within captive populations of Rothschild Giraffes. *Genetics and Biodiversity Journal* 5*:* 159-213.

Burger A. L. Hartig J. Dierkes P. W. 2021. Biological and environmental factors as sources of variation in nocturnal behavior of giraffe. *Zoo Biology* 40: 171-181. https://doi.org/10.1002/zoo.21596

Claxton A. M. 2011. The potential of the human–animal relationship as an environmental enrichment for the welfare of zoo-housed animals. *Applied Animal Behaviour Science* 133: 1-10. https://doi.org/10.1016/j.applanim.2011.03.002

Dahl F. M. Hansen H. H. Vorup, L. D. Jensen L. Ø. Spyridopoulos P. S. Pertoldi C. Alstrup A. K O. Jensen T. H. Pagh S. 2020. Effect of enrichments on behavioural reaction norms of two captive

polar bears (*Ursus maritimus*) in Aalborg Zoo, Denmark. *Genetics and Biodiversity Journal, Special issue (Behavioural Instability):* 61-72.

Duggan G. Burn C. C. Clauss M. 2015. Nocturnal behavior in captive giraffe (*Giraffa camelopardalis*)—A pilot study. *Zoo Biology* 35*:* 14-18. https://doi.org/10.1002/zoo.21248

Facey R. 2017. Evaluation of feeding enrichment for captive giraffes. *3rd Annual Symposium on Zoo Research*: 154-156.

Fangmeier M. L. Burns A. L. Melfi V. A. Meade J. 2019. Foraging enrichment alleviates oral repetitive behaviors in captive red-tailed black cockatoos (*Calyptorhynchus banksii*). *Zoo Biology* 39: 3-12. https://doi.org/10.1002/zoo.21520.

Fernandez L. T. Bashaw M. J. Sartor R. L. Bouwens N. R. Nichole R. Maki T. S. 2008. Tongue twisters: feeding enrichment to reduce oral stereotypy in giraffe. *Zoo biology* 27: 200-212. https://doi.org/10.1002/zoo.20180

Grünberg W. Constable P. D. Kersting K. W. Thompson J. R. Connolly M. J. 2009. Function and dysfunction of the ruminant forestomach. In: Anderson D. E. Rings M. *Food Animal Practice 5th Edition:* 12-19. https://doi.org/10.1016/B978-141603591- 6.10006-5

Gussek I. Große-Brinkhaus C. Südekum K.-H. Hummel J. 2017a. Influence of ration composition on nutritive and digestive variables in captive giraffes (*Giraffa camelopardalis*) indicating the appropriateness of feeding practice. *Journal of animal physiology and animal nutrition* 102: 513-522. https://doi.org/10.1111/jpn.12790.

Gussek I. Hirsch S. Hartmann M. Südekum K.-H. Hummel J. 2017b. Feeding practices for captive giraffes (Giraffa camelopardalis) in Europe: a survey in EEP zoos. *Journal of Zoo and Aquarium Research* 5: 62-70.

Hatt J.-M. Schaub D. Wanner M. Wettstein H.-R. Flach E. J. Tack C. Hässig M. Ortmann S. Hummel J. Clauss M. 2005. Energy and fibre intake in a group of captive giraffe (*Giraffa camelopardalis*) offered increasing amounts of browse. *Journal of veterinary medicine* 52: 485-490. https://doi.org/10.1111/j.1439-0442.2005.00769.x

Hummel J. Clauss M. Baxter E.A. Flach E.J. Johanson K. Fidgett A.L. Eulenberger K. Hatt J. Hume I.D. Janssens G. Nijboer J. 2006a. The influence of roughage intake on the occurrence of oral disturbances in captive giraffids. *Zoo Animal Nutrition* 3: 235 252. https://doi.org/10.5167/UZH-3523

Hummel J. Südekum K.-H. Streich W. J. Clauss M. 2006b. Forage fermentation patterns and their implications for herbivore ingesta retention times. *Functional Ecology* 20: 989-1002. https://doi.org/10.1111/j.1365-2435.2006.01206.x

Johansen K. 2020. Subakut vomacidose og fejlgæring hos browsere og grazerere i zoologisk have. *Brogaarden [in Danish].https://brogaarden.eu/blogs/information-om-eksotiske-dyr/subakut-vomacidose-og-fejgaering-hos-browsere-og-grazerere-i-zoologisk-have?fbclid=IwAR3AVcMxWFi444dBckPwz1-A6V3neRICNQDfmTH2Po6agITpfyWwtgCVr7c, (Accessed 26. January 2022)*

Koene P. 1999. When feeding is just eating: How do farm and Zoo animals use their spare time? In van der Heide D. Huisman E. A., Kanis E. Osse J. W. M. Verstegen M. W. A. *Regulation of feed intake: proceedings of the 5th Zodiac Symposium:* 13-19

Mason G. J. 1991. Stereotypies: a critical review. *Animal Behaviour* 41: 1015–1037.

Monson M. K. Dennis P. M. Lukas K. E. Krynak K. L. Carrino-Kyker S. R. Burke D. J. Schook M. W. 2018. The effects of increased hay-to-grain ratio on behaviour, metabolic health measures, and fecal bacterial communities in four Masai giraffe (*Giraffa camelopardalis tippelskirchi)* at Cleveland Metroparks Zoo. *Zoo biology* 37: 320-331. https://doi.org/10.1002/zoo.21434

Munyaka T. V. Gandiwa E. 2018. An Assessment of Forage Selection by Giraffe Introduced into Umfurudzi Park, Northern Zimbabwe. *Scientifica* 9062868: 1-5. https://doi.org/10.1155/2018/9062868

Ngaha, N. M. I. Massoma, L.D Mandengue, S. H. Yusuf, A.A. 2016. Comparative proximate analysis of leaves and bark of *Alchornea Cordifolia* (Euphorbiaceae). *Journal of Agriculture and Environmental Sciences* 5: 200-206 https://doi.org/10.15640/jaes.v5n1a21

O'Connor D.A. Butt B. and Foufopoulos J.B. 2015. Foraging ecologies of giraffe (*Giraffa camelopardalis reticulata*) and camels (*Camelus dromedarius*) in northern Kenya:effects of habitat structure and possibilities for competition? *African Journal of Ecology, 53:* 183-193. https://doi.org/10.1111/aje.12204

Olsen A. M. Kristensen H. G. Iversen K. W. Pedersen N. H. Pertoldi C. Alstrup A. K O. Jensen T. H. Pagh S. 2020. Assessment of Abnormal Behaviour and the Effect of Enrichment on Captive Chimpanzees at Aalborg Zoo. *Genetics and Biodiversity Journal, Special issue (Behavioural Instability):* 73-91.

Rose, P. Croft, D. 2018. Considering behaviour 24/7: Nocturnal activity and animal welfare in the zoo. *Conference: European Conference on Behavioural Biology*

Okabe K. Kawamura A. Fukuizumi H. Ishiuchi K. Kase C. 2019. Does oral stereotypy in captive giraffes decrease by feeding them evergreens and barks in winter? *Animal Behaviour and Management* 55: 165-173.

Orban D. A. Siegford J. M. Snider R. J. 2016. Effects of guest feeding programs on captive giraffe behavior. *Zoo biology* 35: 157-166. https://doi.org/10.1002/zoo.21275

Ottosen M. P. Kjær J. W. Andersen M. Bach L. A. Pagh S. 2020. Chimpanzees behavioral response to a shift in number of visitors during autumn holiday in Aalborg zoo. *Genetics and Biodiversity Journal, Special issue (Behavioural Instability):* 1-60.

Robert S. Matte J.J. Farmer C. Girard C.L. Martineau G.P. 1993. High-fibre diets for
sows: effects on stereotypies and adjunctive drinking. *Journal of animal science* 37: 297-309 https://doi.org/10.1016/0168-1591(93)90119-A

RStudio Team 2021. RStudio: Integrated Development Environment for R. RStudio, PBC,Boston, MA URL

Sauer C. 2015. Digestive morphophysiology of the giraffe and other wild ruminants. Aarhus University, Faculty of Science and Technology: 119-123

Seeber P. A. Ciofolo I. Ganswindt A 2012. Behavioural inventory of the giraffe *(Giraffa camelopardalis*)**.** *BMC research notes* 5*:* 650–650. https://doi.org/10.1186/1756-0500-5-650

Schüßler D. Greven H. 2017. Quantitative aspects of the ruminating process in giraffes (*Giraffa camelopardalis*) fed with different diets. *Zoo Biology* 36: 407-412. https://doi.org/10.1002/zoo.21386

Sicks F. 2012. Paradoxer Schlaf als Parameter zur Messung der Stressbelastung bei Giraffen (*Giraffa camelopardalis*) (Doctoral thesis). *Goethe University*: 180-184

Tarou L. R. Bashaw J. B. Maple T. L. 2000. Social attachment in giraffe: Response to social separation. *Zoo Biology* 19: 41-51. https://doi.org/10.1002/(SICI)1098-2361(2000)19:1<41::AID-ZOO5>3.0.CO;2-J

Thomsen H. Jensen T.H. Ydesen K. Madsen N. 2020. Use of Ethograms to Analyse Shoaling Behaviour of Mackerel (*Scomber Scombrus*) in an Aquarium. *Genetics and Biodiversity Journal, Special issue (Behavioural Instability):* 131-143.

Wagman J. D. Lukas K. E. Dennis P. M. Willis M. A. Carroscia J. Gindlesperger C. Schook M. W. 2018. A work-for-food enrichment program increases exploration and decreases stereotypies in four species of bears. *Zoo Biology* 37: 3-15. https://doi.org/10.1002/zoo.21391

Young R. J. 1997. The importance of food presentation for animal welfare and conservation. *Proceedings of the Nutrition Society* 56: 1095-1104. https://doi.org/10.1079/PNS19970113

Appendix

A. Giraffe overview

Table 5. Basic information about the giraffes at Aalborg Zoo during the observational period.

Giraffe	Age	Gender	Born at
Basse (Giraffe B)	8 years	Male	Zoologischer Garten Magdeburg
Caroline (Giraffe C)	20 years	Female	Aalborg Zoo
Dumisani (Giraffe D)	1½ years	Male	Aalborg Zoo
Frida (Giraffe F)	7 years	Female	Aalborg Zoo
Maseke (Giraffe M)	8 months	Female	Aalborg Zoo
Qolile (Giraffe Q)	2 years	Female	Aalborg Zoo

B. Browsing material and hay availability

Table 6: Noted times for when the leaves and bark were fully eaten from the branches given in the left and the right side of enclosure.

Date and type of branch	Leaves eaten - Left (time)	Bark eaten - Left (time)	Leaves eaten - Right (time)	Bark eaten - Right (time)
2/10 - Birch	17:57:47	35% remaining	17:00:04 *(4)*	65% remaining
3/10 - L: elm tree R: birch	18:30:38	85% remaining	–	25% remaining
5/10 - Willow	17:14:38	21:48:55 *(17335)*	17:34:28 *(2068)*	21:20:38 *(15638)*
6/10 - Birch	17:15:37	60% remaining	17:06:08 *(368)*	85% remaining
1/11 - Unknown	–	03:45:25 *(38725)*	–	20:00:32 *(10832)*
3/11 - Unknown	–	04:05:54 *(39954)*	–	00:50:22 *(28222)*
4/11 - Unknown	–	21:12:49 *(15169)*	–	00:20:43 *(26443)*
5/11 - Unknown	–	–	–	–

A line indicates that no time could be noted, due to no leaves in the beginning or unidentifiable quantity of bark.

C. Distribution in percent

Table 7: Percentages of time spent expressing each behaviour for each giraffe in each period; observation period

	HF	BR	LO	SS	OS	PA	LD	PS	OOS
	Giraffe B								
OBS1	29.37%	9.82%	0.88%	6.64%	1.44%	0.63%	45.61%	3.08%	2.52%
OBS2	23.39%	11.96%	1.43%	9.60%	0.46%	3.31%	45.71%	4.14%	0%
	Giraffe C								
OBS1	29.75%	2.41%	2.99%	8.68%	4.80%	0.53%	34.63%	1.03%	15.18%
OBS2	22.16%	2.68%	2.31%	8.65%	6.20%	0.04%	33.72%	1.95%	22.28%
	Giraffe D								
OBS1	11.69%	14.67%	1.85%	8.70%	1.51%	0%	49.72%	3.97%	7.89%
OBS2	11.11%	11.64%	2.00%	7.04%	1.46%	0%	54.97%	3.67%	8.11%
	Giraffe F								
OBS 1	20.66%	17.26%	1.37%	5.83%	0.63%	0%	47.75%	2.75%	4.02%
OBS2	17.53%	26.78%	1.51%	5.53%	0.053%	0.040%	36.74%	1.15%	10.67%
	Giraffe M								
OBS1	12.28%	6.42%	2.31%	3.06%	8.05%	0%	59.37%	1.36%	7.16%
OBS2	10.35%	15.93%	1.91%	4.22%	4.11%	0%	55.89%	2.80%	4.80%
	Giraffe Q								
OBS1	10.27%	13.56%	2.05%	11.40%	3.36%	0%	50.89%	1.93%	6.55%
OBS2	12.58%	14.57%	1.70%	10.65%	1.23%	0%	51.41%	2.95%	4.90%

1 (OBS1) and observation period 2 (OBS2). Behaviours consist of the following; "hay feeding" (HF), "browsing" (BR), "locomotion" (LO), "standing still" (SS), "oral stereotypy" (OS), "pacing" (PA), "lying down" (LD), "paradoxal sleep" (PS) and "out of sight" (OOS).

D. Average time spent

Table 8: Average time spent (expressed as percentages) on the behaviours "locomotion" (LO), "standing still" (SS), "lying down" (LD), "paradoxal sleep" (PS) and Feeding (which includes "hay feeding" (HF) and "browsing" (BR) merged) for all six studied giraffes during the observation period 1 (OBS1) and observation period 2 (OBS2).

	Feeding	**LO**	**SS**	**LD**	**PS**
OBS1	29.61 %	1.86 %	8.09 %	48.00 %	2.35 %
OBS2	30.11 %	2.27 %	7.62 %	46.41 %	2.69 %