The relation between age, time budget and sleep pattern of bears in captivity

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Leeuwarden, 2nd of July 2013

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Acknowledgements

We both have never dreamed of doing our first research ever on bears. After both of us worked in a zoo, caring for several species, none of us had much detailed knowledge about the needs of bears and actual discussions around husbandry procedures or the daily activities of bears. However when we arranged ourselves with the study species and conducted literature research on time budget, senescence and sleep pattern, we got interested. Much research related to senescence and sleep pattern is done to get the situation clearer for humans. But only little work was done for the animals the research was carried out on. In the end we are proud that our research is specified on bears only and we hope that our results will be helpful in understanding the husbandry needs of these wonderful creatures.

First of all, we would like to thank our supporting teachers who gave advice and their very own cameras, who answered on, sometimes, desperate e-mails and who were always sure that we would make it and that we pursue our goals. Next, we would like to thank each person of the participating zoos, especially Kris Jansen, head keeper Dierenrijk, and Raymond van der Meer, senior curator DierenPark Amersfoort, who helped us in any way with collecting the needed data and allowed us to study their bears. We also would like to thank Dr. Vicky Melfi who provided a good basis for us, helped to find the right way during the whole process and who gave helpful advice. And last but not least a big thanks to all our family and friends who survived months of conversation with only one topic: bears.

Katharina Herrmann and Emile Prins

Leeuwarden, July 2013

Summary

Due to improved zoo practices, longevity in zoo animals has increased. In comparison to the wild, many species become much older in captivity. Senescence follows a different path in each species and is therefore hard to generalize towards other species. Insights into the process of senescence in animals could provide information which contributes to the housing and husbandry of animals. Few data exist on the deterioration process of captive bears, what possibly may lead to a failure in meeting adapted needs regarding housing and husbandry of elderly bears. The aim of the current research can be outlined as follows: to have insights into behavioural consequences of senescence in captive bears and how a change in sleep pattern is linked to age. To pursue the aim of this research, a total of 11 bears have been observed. The research was carried out in two zoos in the Netherlands: Dierenrijk and DierenPark Amersfoort. The animals were observed on the outside enclosure during day and cameras inside the off-exhibit enclosures recorded the sleep pattern of the bears. Data collection took place in April and May 2013, where each bear was observed for six consecutive days in five sessions per day. Each session contains one hour observation. In order to gain data on the time budget, instantaneous sampling with time intervals of 10 minutes was used. During each session seven scans were recorded, resulting in a total of 210 scans per bear. Sleep pattern was split on day and night observations. Day observations took place next to time budget observations. Continuous recording was used, using the Noldus Pocket Observer. For the sleep pattern during the night, trap cams were used in the off-exhibit enclosure. Pictures were taken on a periodic basis by using time laps mode with intervals of 60 seconds. When movement was detected, a picture was taken, which was defined as a form of activity. A total of four bear were observed during the night, with each bear a maximum of five nights. Data was prepared and analyzed using IBM SPSS 20.0, Microsoft Excel 2010 and Noldus The Observer XT11. Data for time budget was split into active and non-active. In captive bears, activity seems to increase when ageing. Locomotion behaviour is the biggest part of activity. When testing with age, a positive correlation is found with locomotion. Mutual exclusive is non-activity, where resting is the biggest part. Resting has a negative correlation with age. Distributed over the day, activity of the elderly individuals has its peak during the afternoon, while the younger individuals are more active in the morning. A significance difference was found in session 2 between the bears of Dierenrijk and DierenPark Amersfoort. During sessions 2 a feeding presentation was held at DierenPark Amersfoort. Activity increased significantly after the feeding presentation. Sleep in minutes during the day of the bears ranged between 9 minutes and 99 minutes. Per sleeping bout, duration asleep ranged between 5 minutes and 64 minutes. No relation was found between duration asleep and age, and between frequency awake and age. For sleep during the night, also no relations were found between duration asleep and age and between frequency awake and age. Activity patterns of wild bears follow that of food availability, where they are subsequently most of the time diurnal. They may also shift in circadian rhythms to avoid disturbances, such as humans. Because, in captivity, the keepers provide the bears with food, activity is linked to husbandry procedures. Although most research conducted on sleep for bears is focused on hibernation, it can be said that the usage of trap cams is a valuable and inexpensive way to assess the sleep pattern of the bears. Applying these methods on a larger research population with more elderly animals may give a clearer view on the trend of time budget and sleep pattern with ageing. Therefore, this research can be seen as a start to get deeper insights into ageing in captive bears and underlines the fact that the bears' personality influences the behavioural consequences of ageing.

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Introduction

Due to improved zoo practices, longevity in zoo animals has increased (Föllmi, 2005; NSW Government, 2011). For example, while the maximum lifespan in Swamp Wallabies (*Wallabia bicolour*) was 12 years 40 years ago, today some captive wallabies reach an age of 19 years (Nowak, 1991; ISIS, 2011). In comparison to the wild, many species become much older in captivity (Richardson, 2000), for example while 33% of the captive polar bear population (*Ursus maritimus*) are above 20 years of age in captivity (Linke, 1998), only 3% of their wild conspecifics will be able to survive up to this age in Canada (Ramsey and Stirling, 1988). Elderly animals can be of importance for educational purposes in zoological institutions and for scientific research where these animals assist in the understanding of senescence (Longley, 2011).

Senescence follows a different path in each species and is therefore hard to generalize towards other species (Crews, 2007). Senescence affects all organs and body systems (Austad, 1997) and leads to a decrease in mental abilities, which is one of the most striking effects (Veenema, 1998). This is partly due to the degeneration of neurons in the brain and a decrease in brain volume and weight; e.g. in humans between the age of 30 – 90 years, 35% of the hippocampus volume is lost (Anderton, 2002). Research in senescence has mainly focused on rats and mice (e.g. Takeda, 1999) to get insights in the process of senescence for humans. From another point of view, insights into the process of senescence in animals could provide information which contributes to the housing and husbandry of animals. Research focused on senescence of zoo animals has already been conducted for apes (e.g. orang-utan *Pongo* spp.; Weiss *et al.,* 2011). Bears (*Ursidae*) are one of the most popular mammals in zoos (Kitchener and Asa, 2010). While in the wild, they reach an age of around 30 years (Nowak, 1999; Lorenzo, 2009), in captivity both brown bears (*Ursus arctos*) and polar bears (*Ursus maritimus*) can reach an age above 40 years (Lorenzo, 2009). Although suffering from a wide range of diseases, bears are virtually indestructible (Bourne *et al.,* 2010). Up to now it is known that activity budgets in bears change with age (Mountaudouin and Pape, 2004). In captivity is noticed that bears show an abnormal level of reduced activity or hyperactivity (Kleiman, 1996). In nature, polar bears spend round 30% of their day walking and swimming and up to 60% resting (Stirling, 1974; Stirling and McEwan, 1975; DeMaster and Stirling, 1981). The activity of wild polar bears follows that of their prey and most time they hunt in the morning (Lorenzo, 2009). In summer when food is not easy accessible they spend most time resting. Wild brown bears spend up to 20 hours per day active. They spend 80% of their active time on foraging (Lorenzo, 2009). In humans, besides a change in activity budget, done research on sleep pattern found a link between age and sleep disturbance (van Gool *et al.,* 1987; Pandi-Perumal *et al.,* 2002). In animals, general sleep pattern monitoring has been done in nocturnal species and monkeys (Kripke *et al.,* 1968; Affani, 1972). Research on sleep pattern linked to age is done mostly on rats (van Gool, 1983) in order to gather knowledge about human sleep pattern. Sleep disturbance found in humans can be seen as a sign of ageing (Desforges, 1990) and is in depth researched in Alzheimer research (Mendez, 1990; Vitiello, 2001). However in animals, little research on the link between ageing and a change in sleep pattern is done. Knowledge about sleep patterns can give a picture about certain needs an old animal may have and of the deterioration process.

Few data exist on the deterioration process of captive bears, what possibly may lead to a failure in meeting adapted needs regarding housing and husbandry of elderly bears. Developing activity budgets related to age and monitor sleep patterns will make it possible to give a clearer picture of the deterioration process of the bears. This would meet the situation that longevity in zoo animals increases and not much is known about it. Due to the focus on time budget of the bears, general behaviours such as feeding and resting are considered. The aim of the current research can be outlined as follows: to have insights into behavioural consequences of senescence in captive bears and how a change in sleep pattern is linked to age.

1.1 Research questions

The main research question to answer is:

'How does time budget and sleep pattern of captive bears change with age and what is the link between sleep pattern and age?'

To be able to answer the main research question, the following sub research questions have to be answered:

1. How does time budget change with age?
2. How does *duration asleep at night* change with age?
3. How does *duration asleep during day* change with age?
4. How does *frequency awake during night* change with age?

1.2 Term definition

Time budgets: Amount of time the bear spend during observation period on behaviours related to locomotion, social behaviour, foraging, resting and others.

Sleep pattern: Patron of awake and asleep during 24 hours.

2. Material and Methods

2.1 Research population

A total of 11 bears (three polar bears and eight brown bears) have been observed during the data collection period (see appendix 1 for the different individuals). Age in the research population range between 7 and 36 years. One animal was hold alone during data collection and stayed inside for the whole period. The brown bears in Dierenrijk share their enclosure with a group of three European wolves (*Canis lupus lupus*).

Table 1: Overview of the individual bears per enclosure in the different institutions. Merged cells mean that individuals are kept in the same enclosure(s). N.A. = Not applicable.

Institution	Species	Enclosure	Bear #	Other species	age
DierenPark Amersfoort	Brown bear	1	6 10 9 7	N.A.	18 36 31 18
Dierenrijk	Polar bear	1	1 8	N.A.	7 26
		2	11	N.A.	31
	Brown bear	1	2 3 4 5	European wolf	10 12 12 18

2.2 Study area

The research was carried out in two zoos in the Netherlands; Dierenrijk, Mierlo and DierenPark Amersfoort, Amersfoort. The animals were observed on the outside enclosures during day and cameras inside the off-exhibit enclosures recorded the sleep of four animals during night.

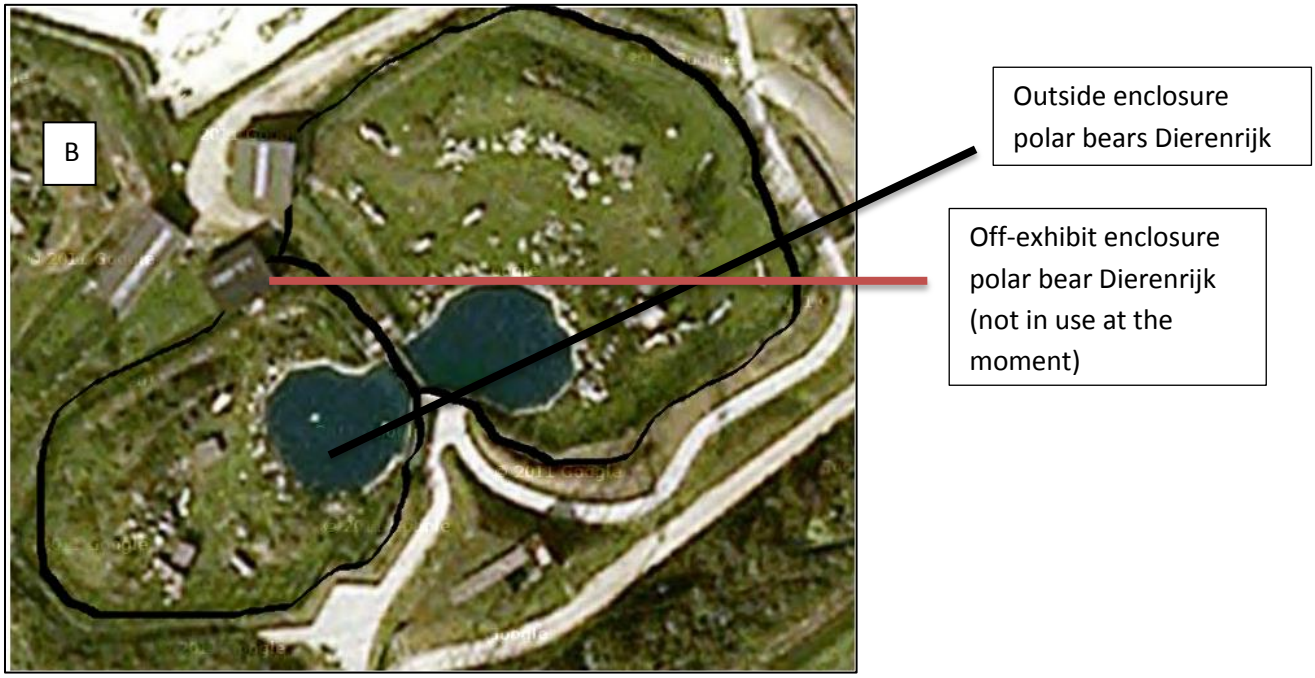
2.2.1 DierenPark Amersfoort

DierenPark Amersfoort has since 1953 bears in its collection. The brown bear enclosure of DierenPark Amersfoort (picture 1) was rebuilt in the year 2012 and is located in the entrance area of the zoo. Special feature is a bridge above part of the outside enclosures where visitors can walk above the animals. The night quarters are hidden behind a sandstone wall and provide a night quarter for each bear. Tree trunks and rocks create possibilities for the animals to climb up and a water body allows the bears to swim. The animals are fed in the morning at 9.15 with vegetables, fruit and bread. The food is spread on the outside enclosure. A public feeding is scheduled at 12.00. Enrichment, e.g. objects to destroy, are provided around 15.00 on the outside enclosures. The bears return to the night quarters at 18.45. Inside they are provided with food (bread and dog biscuits) and straw to lie on.

Picture 1: Brown bear enclosure of DierenPark Amersfoort

2.2.2 Dierenrijk

The polar bear enclosure complex (picture 2) was built in the year 2004. It consists of two outside enclosures. The enclosure of the two observed polar bears is surrounded by grass, sand and rocks. Enrichment in the form of plastic tons, rocks and wood is provided on a daily basis. The water body allows the bears to swim. The off-exhibit enclosures were at the moment of observation not in use by the two bears. The animals stay the whole night and day on the outside enclosure. The animals are fed in the morning at 9.15 with fish, fruit, vegetables and dog biscuits and get occasionally extra food when the animals in the neighbour enclosure are fed at 14.30.



Picture 2: Polar bear enclosure complex Dierenrijk. The B indicates the position of the brown bear enclosure.

The brown bear enclosure (picture 3) is situated next to the polar bear enclosure (B in picture 2) and the animals can see and smell each other. The enclosure consists of plain grass landscape with a water body and places to hide behind wood. The off-exhibit enclosures are not used during night, because the animals stay the whole night in the outside enclosure. The animals are fed in the off-exhibit enclosures in the morning. They stay inside for around 20 minutes while the outside enclosure is cleaned. Additional food is spread on the enclosure.

Picture 3: Brown bear enclosure Dierenrijk

2.3 Data sampling and collection

The collection of data took place in April and May 2013 in DierenPark Amersfoort en Dierenrijk (chapter 2.2). The data per institution was collected on six consecutive days in five sessions per day between 10.15 and 16.30 (table 2). The collection consisted of behavioural observations, both visually and via camera. During the day the data collection consist of both measuring time budget and sleep pattern. A total of 10 bears have been observed during the day. To obtain sleep patterns during the night four bears have been observed on a maximum of five nights.

Table 2: Observation day schedule with the session number and the time of the session. '()' indicates the adapted schedule due to husbandry procedures in DierenPark Amersfoort.

Session	Time		Period of day
	From	Until	
I	10.30 (10.15)	11.30 (11.15)	Morning
II	11.30 (11.15)	12.30 (12.15)	Morning
III	13.15 (12.35)	14.15 (13.35)	Afternoon
IV	14.30 (14.00)	15.30 (15.00)	Afternoon
V	15.30 (15.00)	16.30 (16.00)	Afternoon

2.3.1 Time budget

Time budgets of the bears were measured during daytime by observing the bears on the outside enclosures. One observer observed a maximum of four bears at each time. Measuring time budget, instantaneous sampling with time intervals of 10 minutes was used. Starting at t = 0 minutes, seven

scans per session, per bear were collected. Each bear was observed for a total of 30 hours. This creates a maximum of 210 scans per bear. Recordings of the time budget observations during the day have been noted down on the field form (appendix 2). See table 3 for the ethogram with the different observed behaviours.

2.3.2 Sleep pattern

Continuous sampling is used to measure the sleep pattern during the day. Observations were recorded by using the Noldus Pocket observer. In order to obtain the sleep pattern during the night cameras recorded four bears during the night (20.00 until 08.00). Hereby one camera was used for one bear during the whole night. The used cameras are digital trap cams (e.g. 165 GameSpy Digital Camera) with batteries as power source. Pictures were taken on a periodic basis by using time laps mode with picture intervals of 60 seconds. When the infrared sensor detected movement in the animal a picture was made without flash. Data are saved on 8 GB SD memory cards and every taken picture contained an info strip. On the info strip the time of day when the picture was taken, the location and the temperature were stated. The cameras started to record after the first observation day and were placed in the off-exhibit enclosures.

Table 3: The ethogram with the behaviours to observe, label and the definition of the behaviour.

Behaviour	Label	Definition
Time budget related		
Feeding	Fr	Ingestion of edible material and or consumption of water.
Resting	Re	Sitting or lying, eyes may be closed or not, or a state stance.
Locomotion	Lo	Moves from one location to another at floor level by walking, running or swimming.
Social	So	Behaviour directed at another individual.
Standing	St	With all four food on the ground and not moving.
Other	Ot	Any other behaviour not falling into one of the named categories.
Out of sight	Os	Not in view range of the observer.
Sleep pattern related		
Awake	Aw	Lying with body motionless for at least 60 seconds and eyes closed (not alert).
Asleep	As	Lying with body motionless for at least 60 seconds and eyes closed (not alert).

2.4 Data preparation and analysis

For the preparation of the time budget data, both Microsoft Excel 2010 (hereafter called 'Excel') and IBM SPSS 20.0 (hereafter called 'SPSS') were used. The data analysis is conducted by using SPSS. For the preparation of the sleep pattern data, obtained during the day, Noldus The Observer XT11 was used. For preparing the sleep pattern data obtained during the night, Microsoft Excel 2010 was used. The prepared data was later on copied towards SPSS for conducting the analysis and for the creation of graphs. Significance level was set at $P < 0.05$.

2.4.1 Time budget

The percentage for each behaviour was calculated and the six measured behaviours were divided into two groups, *active* and *non-active*. Where *active* consists of *locomotion*, *feeding*, *social* and *other* and *non-active* consists of *resting* and *standing*.
For analysis, a mean percentage of time spend on each behaviour was used for each individual bear. Using the Pearson correlation coefficient, two-tailed, the mean percentage for each individual bear was used in testing *age* with *active* and with *non-active*. The Pearson correlation coefficient, two-tailed, was also used to test *age* with the six observed behaviours. To test the effect of the time of

the day on the observed ages, a mean percentage per session for each bear was calculated where the data-file was split by session and a Pearson correlation coefficient was used for *age* with *locomotion* and with r*esting*. Before conducting statistics, the different measured behaviours were tested for normality using the Shapiro-Wilk test. The Mann-Whitney U test was used to test for the *activity* of the bears in the two different institutions. In order to test for the effect of the feeding presentation held in DierenPark Amersfoort on the *activity* of the bears, the Wilcoxon signed rank test was used.

2.4.2 Sleep pattern

Data of the sleep pattern during the day was from the Pocket Observer put into The Observer XT11, what was prepared for further analysis. From this data, variables duration *asleep-during-day*, duration *asleep-per-sleeping-bout*, *mean-percentage-slept-per-day* and relative frequency *awake-during-day* were calculated and copied towards Excel and later on towards SPSS. From each variable, the mean per observation day was calculated. Relative frequency *awake-during-day* was calculated by dividing the frequency awake during the day through the total minutes slept during the day. In SPSS, correlations between *age* and duration *asleep-during-day* and with relative frequency *awake-during-day* were tested with the Pearson correlation coefficient, two-tailed.

Data obtained for the sleep pattern during the night was directly put into Excel where it was prepared for further analysis in SPSS. For each individual bear, a percentage *active* and *sleep* was calculated. This was done by defining each picture as an act of activity and dividing the pictures taken per night through the total minutes per night. Sleep was defined as the time between two pictures was >12 minutes, subsequently, frequency awake could be calculated from this. The percentage *sleep-per-night* is mutual exclusive from the percentage *activity*. The variables percentage *sleep-during-night*, percentage *activity-during-night* and relative frequency *awake-during-night* could be calculated from the prepared data. For each variable, a mean was calculated per night. Relative frequency *awake-during-night* was calculated by dividing the frequency awake during the night through the total minutes slept during the night. To correlate with *age*, the Pearson correlation coefficient, two-tailed, was used.

3. Results

To gain insights into age related time budgets and sleep pattern of captive bears, three polar bears and eight brown bears were observed (table 4) for six consecutive days, five hours per day, in April and May 2013. This results in a total of 210 scans per bear. For some individuals, less scans were achieved due to limited sights. *Sleep-pattern-during-day* was measured simultaneously with measuring time budget. Using trap cameras in the off-exhibit enclosures, *sleep-pattern-during-night* was measured.

Table 4: Number of bears observed for the different research issues.

Research Issue	Brown Bear	Polar Bear
Time budget	2.6 (2 males, 6 females)	1.1
Sleep during day	2.6	1.1
Sleep during night	2.1	0.1

3.1 Time budget

The researched activities were divided into active behaviours (*locomotion*, *feeding*, *social* and *other*) and non-active behaviours (*resting* and *standing*).

3.1.1 Active

Although there seems to be an increasing trend (figure 1), no significant correlation could be found between *age* and *activity* (Pearson correlation coefficient; r = 0.57, n = 10, p = 0.085).

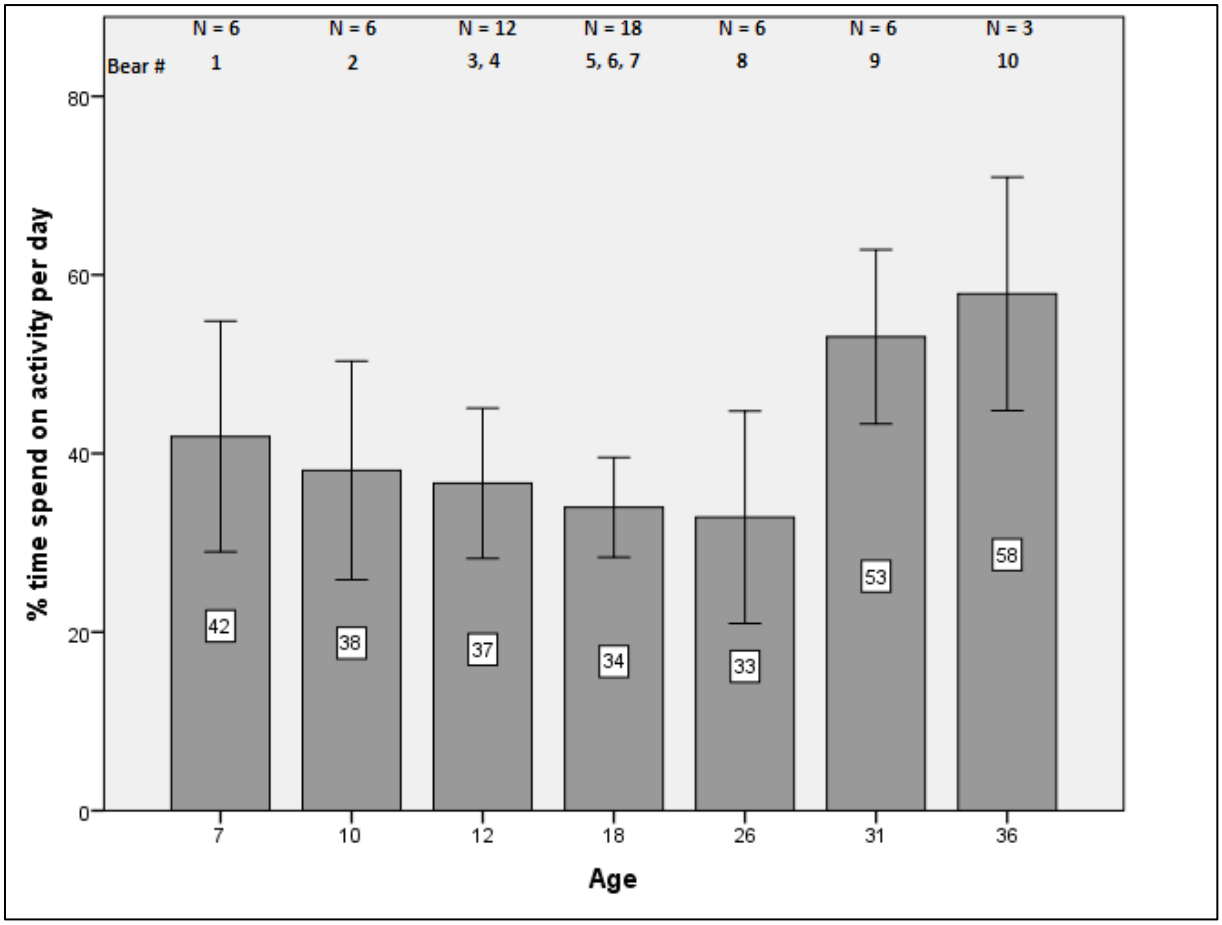


Figure 1: Mean percentage time spend on *active* per day for each *age* of the bears in years ± SE. Per bar, N is number of observation days per observed *age*.

The observed activity of the animals is mostly based on *locomotion*, but other behaviours shape the time budget too (table 5).

Table 5: Mean percentage time spend on activity behaviours per day ± SE .

Bears	Age	Locomotion	Feeding	Social	Other
1	7	21% ± 4.3%	5.2% ± 1.9%	2.9% ± 1.4%	12.9% ± 3%
2	10	9% ± 2.2%	15.7% ± 4%	0%	13.3% ± 3.1%
3 and 4	12	11.9% ± 2.5%	11.9% ± 2.4%	11% ± 2.3%	1.9% ± 0.7%
5, 6 and 7	18	15.9% ± 2%	7% ± 1.4%	1.9% ± 0.6%	9.2% ± 1.6%
8	26	21.4% ± 4.6%	4.8% ± 1.6%	2.4% ± 1.2%	4.3% ± 1.8%
9	31	46.4% ± 4.6%	5.1% ± 1.7%	0%	1.5% ± 1.1%
10	36	45.7% ± 5.9%	7.6% ± 3.1%	0%	4.6% ± 2.8%

In the younger animals more time was spend on activities like *feeding* and *othe*r. In some animals *social* behaviour was not observed. A positive correlation is found between *age* and *locomotion* (Pearson correlation coefficient; r = 0.841, n = 10, p = 0.002) and also a correlation is found for each session, except for session 1 (table 6).

Table 6: Pearson correlation coefficient per session for *age* and *locomotion*.

Session		r	n (days)	p
I	morning	0.18	57	0.18
II	morning	0.38	56	0.004
III	afternoon	0.593	56	0.000
IV	afternoon	0.451	57	0.000
V	afternoon	0.472	57	0.000

In general, *activity* varies not only between *age* but also over the day. The younger individuals have been more active in the morning (sessions 1 and 2) and less active in the afternoon (sessions 3, 4 and 5) while the opposite counts for the older individuals (figure 2).

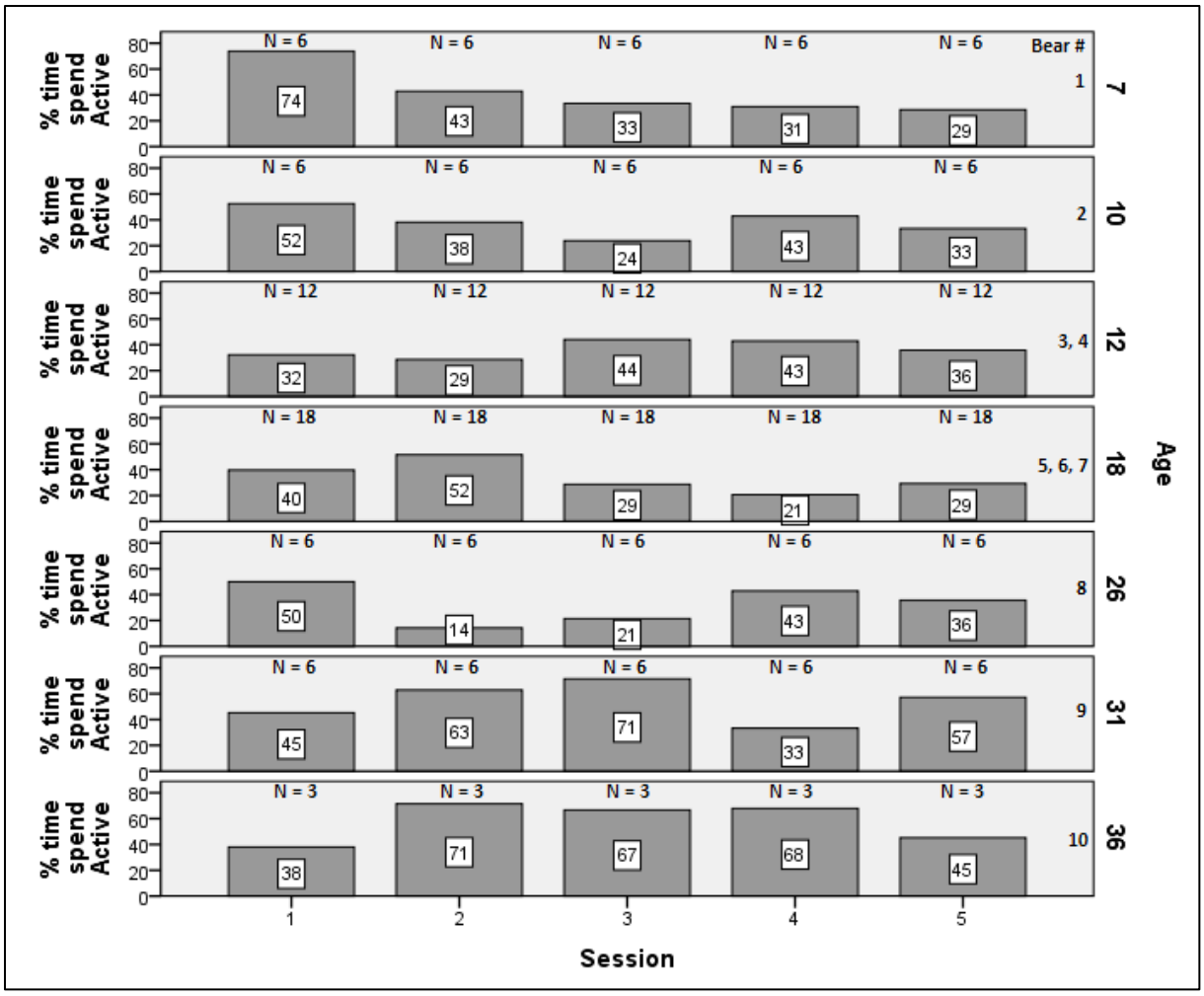


Figure 2: Mean percentage time spend *active* per session per *age* of the bears in years. Per bar, labels indicate the percentage and N is the days observed. Next to *age*, the bear number is stated.

A higher level in activity was only in the morning (session 2) observed in the bears of DierenPark Amersfoort in comparison to the bears of Dierenrijk (Mann-Whitney U test; U = 163.5, p = 0.001). During the observation period, each day a brown bear feeding presentation was held at DierenPark Amersfoort at 12.00h, which was during session 2. Looking at the estimated percentage time spend on activity one hour before (pre-presentation period) and one hour after (post-presentation period) the feeding presentation, a significant difference in the *activity* of the animals is recorded (Wilcoxon signed rank test; Z = -2.173, p = 0.03)(figure 3). In Dierenrijk (no feeding presentation), the animals were during the morning (session 2) less active (31.7% ± 5.1% of the time) than the bears in DierenPark Amersfoort (61.4% ± 4.5% of the time). The occurrence of a feeding presentation is related with the animals' *activity*.

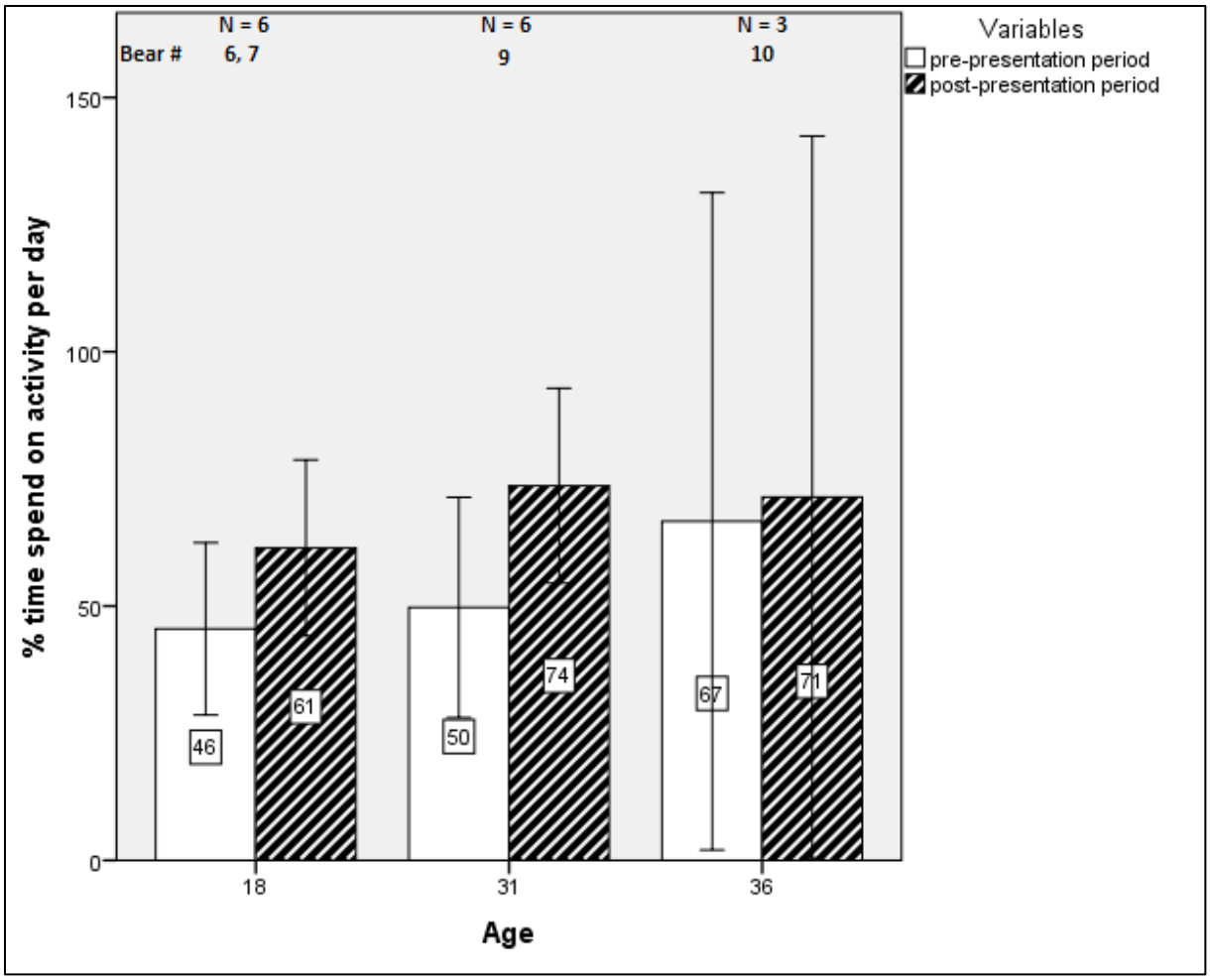


Figure 3: Mean percentage time spend on activity per day during pre-presentation period and post-presentation period for the observed *age* (in years) of the bears in DierenPark Amersfoort ± SE. Per bar, N is number of observation days per observed age.

3.1.2 Non-active

There is a negative correlation between *age* and *resting* (Pearson correlation coefficient; r = -0.743, n = 10, p = 0.014). *Resting* is the biggest *non-active* behaviour with *standing* the smallest (table 7).

Table 7: Mean percentage time spend on the different non-active behaviours per day per age ± SE.

Bear	Age	Resting	Standing
1	7	53.8% ± 6.8%	4.3% ± 1.4%
2	10	56.7% ± 6.3%	5.2% ± 1.7%
3 and 4	12	57.6% ± 4.2%	5.7% ± 1.2%
5, 6 and 7	18	55.1% ± 3.5%	10.5% ± 1.6%
8	26	56.7% ± 6.4%	10.5% ± 2.4%
9	31	36.7% ± 5.1%	6.7% ± 1.9%
10	36	29.7% ± 5.6%	12.4% ± 4.2%

With the exception of session 1 and session 4, a correlation between *age* and *resting* could be found (table 8).

Table 8: Pearson correlation coefficient per session between *age* and *resting*.

session		r	n (days)	p
I	morning	0.036	57	0.788
II	morning	-0.291	57	0.028
III	afternoon	-0.302	57	0.022
IV	afternoon	-0.047	57	0.729
V	afternoon	-0.304	57	0.022

3.2 Sleep pattern during day

In all ages, resting for longer periods resulted into sleep. While older animals often only lay down to fall asleep, younger animals looked attentively around while already lying. The maximum number of minutes slept during the day ranged from 9 minutes (bear of 36 years) up to a total of 99 minutes (bear of 26 years)(table 9). The maximum number of minutes slept during the day however varied within individuals of the same age (e.g. one of the 18 year old individual slept for a total of 45 minutes, while the other one slept for 91 minutes). The minutes slept during the day varied and there is an increase in duration *asleep-during-day* (figure 3).

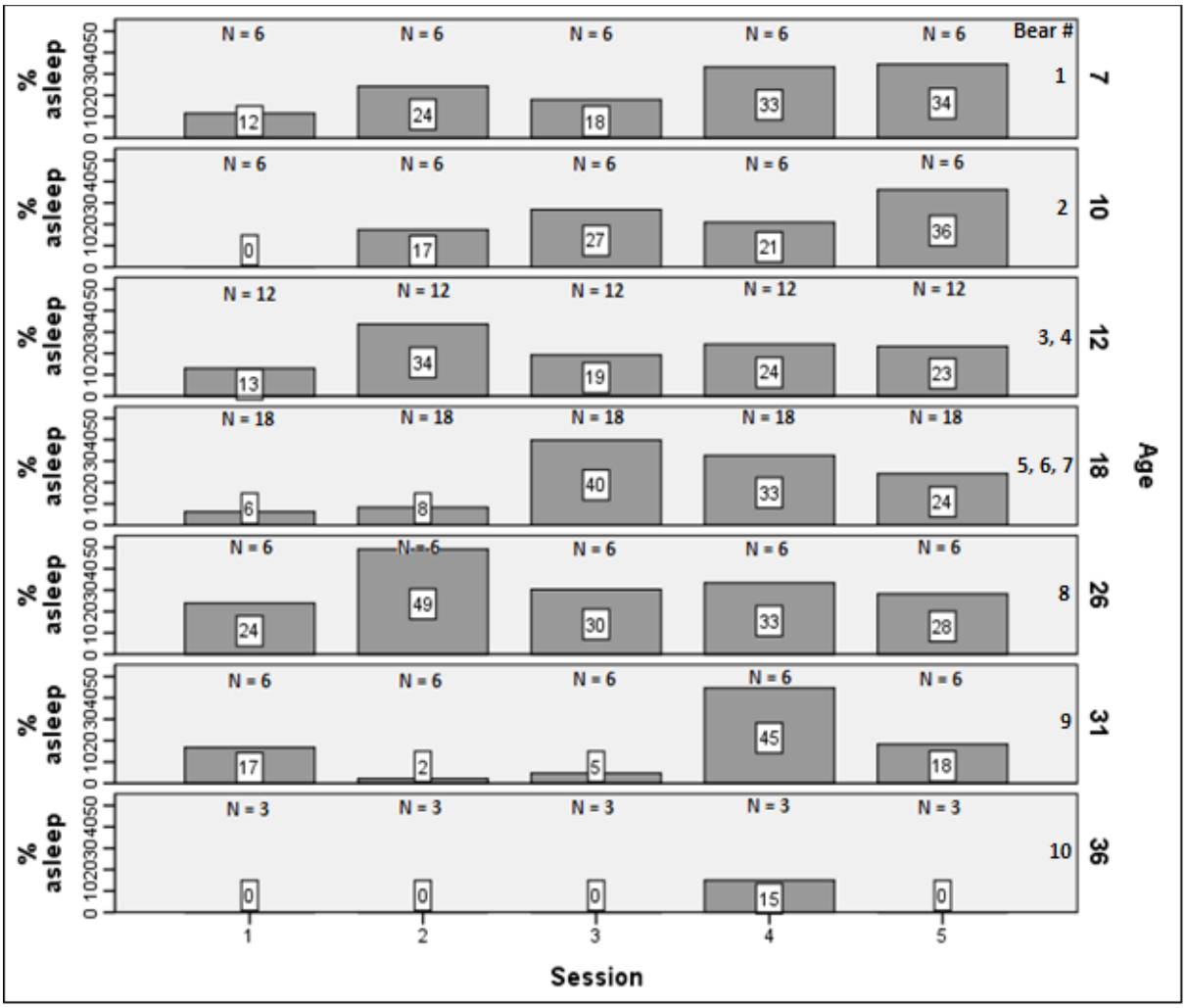


Figure 3: Mean percentage *asleep* per session per *age* of the bears in years. Per bar, labels indicate the percentage and N is number of observation days per observed age.

The total duration *asleep-during-day* was on average up to 14 times interrupted where no correlation between the relative frequency *awake* and *age* is found (Pearson correlation coefficient,

r = 0.495, n = 10, p = 0.146). The sleep during the day of older bears is not as often interrupted as the sleep of young bears (table 9).

No significant correlation could be found for *age* and duration *asleep-during-day* (Pearson correlation coefficient; r = -0.434, n = 10, p = 0.21), which might be due to the fact that there are big differences in duration *asleep-during-day* between individuals of the same age. The duration of a sleeping bout varied between 5 minutes and up to 64 minutes and the number of minutes slept in one sleeping bout also varied between bears of the same age (table 9).

Table 9: Mean minutes slept per day, mean frequency awake per hour, frequency awake during observation day and mean minutes slept per sleeping bout in all individuals.

Bears #	Age	Min. sleep during day	Percentage sleep during day	Relative frequency awake	Min. 'sleep' per sleeping bout
1	7	73	24,3	0.19	21
2	10	61	20,3	0.2	17
3	12	84	27,9	0.14	39
4	12	53	27,5	0.28	13
5	18	45	14,8	0.18	32
6	18	91	30,1	0.09	64
7	18	56	18,5	0.18	33
8	26	99	33	0.12	51
9	31	52	17,2	0.15	39
10	36	9	3	0.67	5

3.3 Sleep pattern during night

Most of the observed bears spend a great part of their time during the day resting and sleeping (figure 3 and table 9). If the animal rests and sleeps a great part during the day the questions arise how much do they sleep at night, how often is the sleep interrupted and how active are they during the night In order to gain this information three brown bears of the age 18, 18 and 36 and one polar bear with the age of 31 have been monitored by trap cameras during the night in the off-exhibit enclosures (table 10). Detected activity in the animal resulted in a picture. On some days the 36 year old individual refused to go outside and choose to spend the entire day alone in the off-exhibit enclosure. The 31 year old individual (bear #11) was continuously due to medical treatment in the off-exhibit enclosure.

Table 10: Minutes slept per night, percentage *activity* and frequency *awake-during-night* in the four observed individuals.

Bears #	Age	Min. sleep per night	Percentage sleep during night	Percentage activity during night	Relative frequency awake	Total number of pictures taken
6	18	562	93,2	6,8	0.011	197
7	18	600	98,5	7,5	0.016	54
11	31	617	95,3	4,7	0.006	170
10	36	544	86,1	13,9	0.018	251

The calculated relative frequency *awake-per-night* shows no difference between the ages and there are only minor differences in the calculated mean percentage *activity-during-night*, however the distribution of the animals' activity during night differs (figure 4).

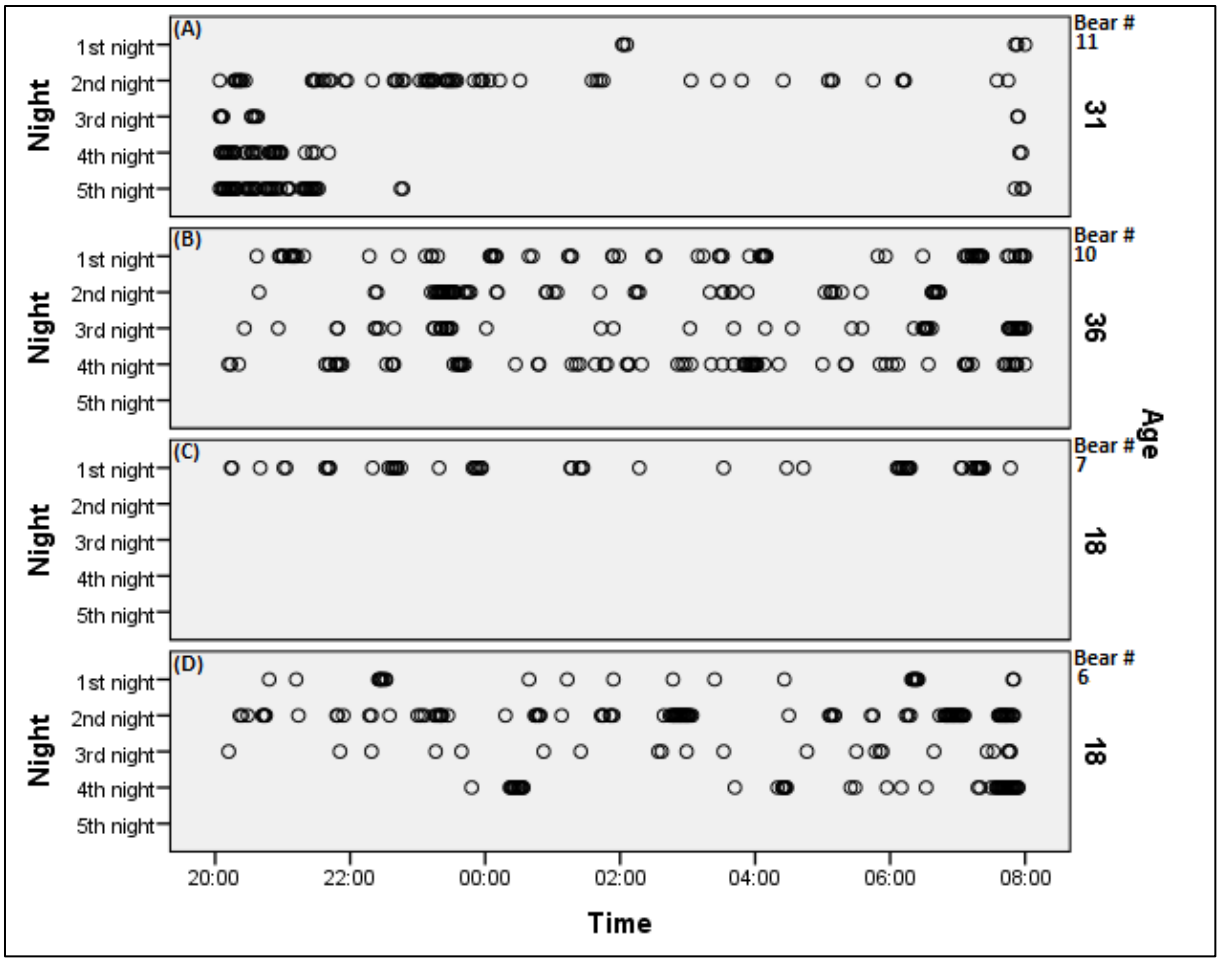


Figure 4: The pictures taken for the four different observed bears, with (A) 31 year old polar bear, (B) 36 year old brown bear, (C) 18 year old brown bear, (D) 18 year old brown bear. Movement of the bear triggered trap cam to take a picture.

The 31 year old individual shows a comparable pattern in the different nights, where it is mostly active short after 20.00h and short before 08.00h. The hours asleep are most of the time from around 22.00h until 07.00h (figure 4A). In comparison to the 31 year old individual, the 36 year old individual shows a dissimilar pattern in the observed nights. It is active for most periods of the night and no rough pattern could be found (figure 4B). The younger animals (both 18 years old) show both a similar pattern in the activity, spending most of the time during the night *active*, no pattern can be described where clusters of pictures, which states *activity*, vary greatly between the nights (figure 4C and 4D).

No correlations could be found when testing *age* with percentage *sleep-during-night* (Pearson correlation coefficient; r = -0.393, n = 4, p = 0.607), with percentage *activity-during-night* (r = 0.516, n = 4, p = 0.484), and with relative frequency *awake-during-night* (r = -0.298, n = 4, p = 0.702). This states that no pattern could be found between *age* and sleep in the captive bears.

4. Discussion

In general the aim of this research, to gain more insights into behavioural changes of senescence in captive bears and how sleep pattern is linked to age, is achieved by the use of behavioural observation methods during the day and monitoring the bears with trap cameras during the night. Both methods outlined a broad variation in data between the researched animals.

4.1 Time budget

The findings in time budget, in the observed bears of different ages is underlined by results found in other researches. In this research, 37% of the polar bears and 39% of the brown bears time is spent active. Far higher results for polar bears were found by Ames (1993) where was concluded that the bears are active for 50%- 60% during day. Another study on 243 captive polar bears, European brown bears (*Ursus arctos arctos*) and Himalayan black bears (*Ursus thibetanus thibetanus*) stated that the bears are active between 50% - 70% of the time they spend outside (Keulen-Kromhout, 1974). In not many researches about activity and time budget the results are linked to the age of the bears, however Vickery and Mason (2004) found that older bears became less active in their research at Asiatic black bears (*Ursus thibetanus*) and Malayan bears (*Helarctos malayanus*). Although this conclusion is contradictory with the results of this research, it has to be considered that the research population of this research consisted of two polar bears and eight brown bears, where the research population of Vickery and Mason (2004) consisted of 18 Asiatic black bears and 11 Malayan bears. The age of the research population of this research varied between 7 and 36 years, while that of Vickery and Mason (2004) varied between 1.5 and 11 years. The maximum age of the research population of Vickery and Mason (2004) combined with that they found lower activity in the older bears, supports the findings in this research where activity slightly decreases in the bears when ageing up to 26 years of age. A study by Kaczensky *et al.* (2006), on wild brown bears in Croatia and Slovenia found that daytime activity is significantly different between adults (39%), sub-adults (52%) and yearlings (64%) where adults are for a longer period non-active during day and active throughout the whole night. However it has to be noted that the maximum age of the observed bears is not above 13 years so the conclusions are more applicable for 'adult' bears then for 'old' bears. This too underlines the results of this research. Focused more on elderly bears little research has been done on their activity patterns because in nature, only a few individuals survive up to an age of 20+ years (Ramsey and Stirling, 1988). Studies on brown bears show that season influences the level of activity (Lorenzo, 2009, Hissa *et al.,* 1994). Daytime activity may change from 14 hours in the summer months to 20 hours during the winter months (Lorenzo, 2009). While in nature, around 80% of the active time is spend on foraging in brown bears, in this research *feeding* behaviour ranges between 4.8% and 15.7% during the day. Grandia *et al.* (2000) found that activity was increased when increasing the number of feedings from three to six on a daily basis. In this research, activity was significantly increased after the daily feeding presentation held at DierenPark Amersfoort. In a study on Malayan sun bears the hiding of food to let the animals search for it and the provision of different feedings during the day increases the animals' time spend on e.g. locomotion (9.64%), exploratory behavior (31.52%) and feeding (25.69%) (Cheng, 2001). Time budget between the bears in this research demonstrated differences in *activity* related to *feeding* and *other* and no *social* behaviour was observed in some bears. This could be due to the personality of the bears (Fagen, 1996), regarding the *social* behaviour, Latour (1981) found that wild polar bears interacted more with conspecifics of the same age group.

For the oldest individual (36 years of age), less scans were achieved, because this individual stayed voluntarily for three of the six observation days in the off-exhibit enclosure where she was not visible for public and alone during day.

As found in this research *activity* varies between the institutions. According to Stirling (1974) the activity pattern of wild polar bears is linked to the activity pattern of their main prey species, ringed seals (*Phoca hispida*). The seals haul out in great numbers in the afternoon to rest on the ice,

where the polar bears will become active for hunting on the seals. This was also found by Messier *et al.* (1992). Munro *et al.* (2006) found that foraging behaviours of wild grizzly bears (*Ursus arctos horribilis*) differed over the seasons when food availability changed. Due to the fact that activity of wild bears depends upon food availability, this might suggest that the same is applicable for captive bears. As can be seen from the results of this research, the bears are most active during the morning (session 1) where there is a lot of keeper activities around the enclosure. Due to the fact that the keepers provide food for the bears, this might explain that activity increases with the keepers' presence (Duncan, 1994; Shepherdson, 1998). Overall, bears perform little activity at night (e.g. Reid *et al.,* 1991; Bridges *et al.,* 2004; Paisley and Garshelis, 2006), the same was found in this research where the highest *activity* at night was 13.9% in the 36 year old female brown bear. While during spring and summer wild bears are more diurnal, in autumn bears are seen to be more active during the night (Reid *et al.,* 1991). Foraging behaviour might play a role in this. Klinka and Reimchen (2002) found that wild brown bears were more active in autumn because of the hunting and feeding on the salmons which are easier to catch in the dark-hours. Although most food is accessible for bears both day and night in the wild, foraging during the day enables the bear to use their sight (Paisley and Garshelis, 2006). Given the fact that *activity* of the captive bears might be linked to the keepers' routine, least *activity* of the bears in this research is seen at night when there is no food available. Powell (1997) found that American black bears (*Ursus americanus*) are mainly diurnal, but may become nocturnal to avoid humans and so points out that bears are able to adapt their activity pattern to their surroundings. This is underlined by Paisley and Garshelis (2006) who found that wild sub adult male Andean bears (*Tremarctos ornatus*) were mostly diurnal, having very little activity during the dark hours.

4.2 Sleep pattern

Due to the fact that bears are very adaptive regarding their activity patterns, the same may be applicable for their sleep pattern. Looking at the results of this research, bears slept most of the time in the afternoon, while there were no activities of animal keepers. Larivière et *al.* (1994) found in a study on activity in 15 wild female black bears that activity of the bears stopped on average 141 minutes after sunset, the bears became active again by an average of 30 minutes after sunrise. This states that the bears slept during most time of the night. Nearly the same is found in this research. When looking at the link between *age* and *duration-asleep-during-day*, no correlation was found in this research. No comparative studies on bears and sleep linked with *age* have been conducted yet. However similar studies are conducted on other species. Noser *et al.* (2003) found a negative correlation between *sleep duration* and *age*, in a study on the relation between sleep and social status of gelada baboons (*Theropithecus gelada*). They also made use of cameras in the enclosure. The difference to be noted is that they made use of continuous recordings while in this research pictures were taken when movement of the bear was detected. In contrast a study by Tobler and Schwierin (1996) found no correlation between *duration asleep* and *age.* In their research on sleep behaviour of captive giraffes (*Giraffa camelopardalis*) they also made use of trap cameras with continuous recording. Wong *et al.* (2004) used trap cameras for measuring activity patterns of wild Malayan sun bears in Borneo. Just as done in this research, Wong *et al.* (2004) assumed that pictures taken at various times are correlated to activity periods of the bears. Therefore, in this research the percentage activity was calculated, the time spend *non-active* during the night was interpreted as time spend on *sleep*.

Looking at the pictures taken there were also short periods *active* for each bear during the night. Research in humans found a disturbed sleeping pattern in healthy elderly men and women, compared to healthy younger individuals (Vitiello et al., 2004). Jelicic *et al.* (2002) found that sleep problems of humans is followed-up by cognitive decline a few years later. Research on sleep pattern of zoo animals is based on only a few studies, e.g. Tobler (1996), and due to that, sleep pattern is studied in a limited number of species (Campbell and Tobler, 1984). In bears up to now, most research was focused on hibernation (e.g. Robbins *et al.,* 2012) and activity patterns (e.g. Kozakai *et*

al., 2013). Scientists are divided in the opinion whether sleep in mammalian species can be compared to each other (Siegel, 2009) or not (Lesku *et al.,* 2006).

Older animals are more prone to suffer from health problems (Jessup and Scott, 2011). In general, zoos aim to maintain a good level of welfare in captive animals (BIAZA, 2013; Hosey *et al.,* 2009), but let them often unknowingly live long and painful lives (Föllmi *et al.,* 2007). Although this research was not focused on defining health problems in elderly animals, the same methods could be used with the aim of getting insights into health problems in elderly animals.

Overall, the conducted research gives insights into the relation between age, time budget and the sleep pattern of captive bears. Knowing these relations is helpful in understanding the behavioural consequences of ageing in captive bears. The methods used for this research appear to be suitable for further research, with general behaviours for assessing the time budget and the usage of trap camera's for obtaining data on the sleep pattern during the night. This is an inexpensive way to obtain the wished data, many zoos holding polar bears are already monitoring their inside enclosures when the female polar bears raise their offspring. Conducting more research on the behavioural consequences of ageing in captive bears will give more insights into this process. Because there seems to be no trend between the different aspects of the sleep pattern and *age* of captive bears, one might question if there are changing needs in husbandry for the elderly individuals. In fact, overall activity of the adult bears seems to be low in comparison to other conducted researches on activity patterns of bears, one might suggest that influences of husbandry or of the individual characteristics play a certain part in this. Therefore, adapting husbandry needs for elderly bears seems not to be in place. Applying these methods on a larger research population with more elderly animals may give a clearer view on the trend of time budget and sleep pattern with ageing. Therefore, this research can be seen as a start to get deeper insights into ageing in captive bears and underlines the fact that the bears' personality influences the behavioural consequences of ageing.

5. Conclusion

To be able to answer the main research question, the following sub research questions have to be answered:

1. How does time budget change with age?
   These elderly captive bears spend more time on activity than younger individuals, with *locomotion* as the most performed behaviour of activity. Non-activity is mutual exclusive from this, with *resting* as the most performed behaviour of non-activity. However there is a relation between the feeding presentation and an increase in activity of the bears of DierenPark Amersfoort.

2. How does duration asleep at night change with age?
   No relation was found for duration *asleep-during-night* and *age*, stating that the duration of sleep during the night did not differ with ageing.

3. How does duration asleep during day change with age?
   There are big differences in duration *asleep-during-day* between the individuals of the same age. No correlations could be found when testing *age* with duration *asleep-during-day*.

4. How does frequency awake during night change with age?
   No correlation between the frequency *awake-during-night* and *age* is found. Stating that, the frequency of sleep during the night did not differ with ageing.

The main research question to answer is:
'How does time budget and sleep pattern of captive bears change with age and what is the link between sleep pattern and age?'
Overall, the activity of captive bears seems to increase when ageing, however this could be related to husbandry procedures of the holding institution. When looking at the behaviours, *locomotion* is the biggest part of activity and *resting* is the biggest part of non-activity. There were no correlations found between the different aspects of sleep pattern and *age*. Stating that there was no trend in sleep pattern with ageing of the captive bears.

As outlined before, results vary between different researches and make it hard to generalize outcomes. However the used method is suitable for further research within this frame due to low material costs and an easy way to obtain the data. The activity with the younger bears in this research is lower than found before in other researches and no relation between sleep pattern and age was found. Therefore, one might question if changes have to be made in husbandry when bears become older. At the end, applying these used methods to a bigger research population will give a clearer view on the trends in behavioral changes with ageing.

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Software

ISIS 2011, ursus studbooks

Appendices

Appendix I Research population

Brown bears (*Ursus arctos*)
Institution: DierenPark Amersfoort

ID:	**6**		
House name:	Kokkie	**Age:**	18
Sex:	1.0		
ID:	**10**		
House name:	Bolke	**Age:**	36
Sex:	0.1		
ID:	**9**		
House name:	Moeky	**Age:**	31
Sex:	0.1		
ID:	**7**		
House name:	Peppie	**Age:**	18
Sex:	1.0		

Institution: Dierenrijk

ID:	**2**		
House name:	Hryzula	**Age:**	10
Sex:	0.1		
ID:	**3**		
House name:	Laura	**Age:**	12
Sex:	0.1		
ID:	**4**		
House name:	Brigitta	**Age:**	12
Sex:	0.1		
ID:	**5**		
House name:	Ljalja	**Age:**	18
Sex:	0.1		

Polar Bears (*Ursus maritimus*)
Institution: Dierenrijk

ID:	**11**		
House name:	Wash	**Age:**	31
Sex:	0.1		
ID: 29954787	**8**		
House name:	Beja	**Age:**	26
Sex:	0.1		
ID:	**1**		
House name:	Henk	**Age:**	7
Sex:	1.0		

Appendix II Field form

Session 1							
Individual	0 min.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
.....							
.....							
.....							
.....							

Session 2							
Individual	0 min.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
.....							
.....							
.....							
.....							

Session 3							
Individual	0 min.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
.....							
.....							
.....							
.....							

Session 4							
Individual	0 min.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
.....							
.....							
.....							
.....							

Session 5							
Individual	0 min.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
.....							
.....							
.....							
.....							

Control	
Observer	KH / EP
Species	PB / BB
Institution	1 / 2 / 3 / 4
Group	...-...-...
Other spec.	YES / NO

Comments