

# Behavioural and physiological correlates of personality in greylag geese (*Anser anser*)

Simona Kralj-Fišer · Brigitte M. Weiß · Kurt Kotrschal

Received: 8 April 2009 / Accepted: 28 November 2009  
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**Abstract** Personality means suites of correlated behavioural traits, also referred to as “behavioural syndromes” or “personality dimensions”. Across animal taxa similar combinations of traits seem to prevail, which may have proximate foundation in common neuroendocrine mechanisms. Hitherto, these have been rarely studied in intact social settings. We investigated personalities of greylag goose males from a free-roaming flock that shows complex social relationships. In connection with our longitudinal study on the consistency of behavioural and physiological responses to multiple challenges, we asked whether and how single, personality-related behavioural traits correlate with each other to form personality dimension(s). We tested whether these dimensions were related to physiological characteristics that previously showed limited plasticity (heart rate (HR), baseline and stress-induced excreted immuno-reactive corticosterone (BM), and testosterone metabolites levels) and, furthermore, to age, body measures, and dominance rank. Principal-components analysis based

on behavioural variables revealed two factors: 51.1% of variability was explained by “aggressiveness” and a further 19.1% by “sociability”. “Aggressiveness” comprised correlated measures of aggression, subordination, boldness, vigilance, and proximity to the mate. This “aggressiveness” positively correlated with stress-induced BM levels, the HR increase during aggressive interactions, and with dominance rank, which may suggest proximate and functional contingencies of this personality dimension.

**Keywords** Aggressiveness · Behavioural syndromes · Corticosterone · Dominance · Heart rate · Personality · Sociability

## Introduction

Individuals of the same sex and age within a given population/species often differ from each other in their behaviour. Such individual differences in response to the ecological and social environment, if relatively consistent over time and across conditions or situations, are regarded as major attributes of personality (Zuckerman 1991). Personality comprises suites of correlated behavioural traits which are also referred to as “behavioural syndromes” (Sih et al. 2004). These may range in complexity from correlations of as few as two behaviours, e.g. aggression and boldness, to complex personality dimensions based on factor analysis (Gosling and John 1999). Personalities are widespread among animal taxa (Bell 2007), are often contingent with physiological and neuroendocrine correlates (Koolhaas et al. 2001), can be heritable (van Oers et al. 2005), and may be fitness-relevant (Dingemanse and Réale 2005).

Some personality dimensions are species-specific, whereas others—aggressiveness, boldness, activity, and

S. Kralj-Fišer · B. M. Weiß · K. Kotrschal  
Konrad Lorenz Forschungsstelle für Ethologie, Grünau, Austria

S. Kralj-Fišer (✉)  
Jovan Hadži Institute of Biology,  
Scientific Research Centre of the Slovenian Academy  
of Sciences and Arts, Novi trg 2, P.O. Box 306,  
1001 Ljubljana, Slovenia  
e-mail: simonakf@gmail.com

B. M. Weiß  
Institut de Biologie, University of Neuchâtel,  
Neuchâtel, Switzerland

K. Kotrschal  
Department for Behavioural Biology,  
University of Vienna, Vienna, Austria

sociability—show strong cross-species generality (Gosling 2001). In several species, individuals may be classified by their behavioural and physiological effort to master stressful situations (Koolhaas et al. 2001): extremes of behavioural continua have been found to vary along a “reactive-proactive” dimension (e.g. wild house mice, *Mus musculus domesticus*, Benus et al. 1991; domestic pigs, *Sus scrofa*, Hessing et al. 1993; great tits, *Parus major*, Groothuis and Carere 2005) comprising correlated measures of aggression, activity, fearfulness, exploratory behaviour, response to environmental change, and social attachment. A proximate explanation for why some behaviours are correlated, i.e. come in packages or personality dimensions, could involve a common causal connection between traits: they may be modulated by the same genes or the same hormones (pleiotropy) via genetic or epigenetic mechanisms (Daisley et al. 2005; Groothuis and Carere 2005).

Behavioural differences in several species are related to differences in their stress response, e.g. direct or indirect measures of catecholamine (laboratory rats, *Rattus norvegicus*, Sgoifo et al. 2006; hen, *Gallus gallus*, Korte et al. 1997) and corticosterone levels (rodents, *Mus musculus*, *Rattus norvegicus*, Koolhaas et al. 2001; great tit, *Parus major*, Carere et al. 2003; rainbow trout, *Oncorhynchus mykiss*, Øverli et al. 2005); and to differences in androgen levels (rodents, *Mus musculus*, *Rattus norvegicus*, Koolhaas et al. 2001). In contrast with studies in laboratories, research in unselected animal lines or semi-free animals generally failed to show the relationship between personality traits and hypothalamus–pituitary–adrenal (HPA) axis (re)activity (e.g. shelter dogs, *Canis familiaris*, De Palma et al. 2005; rabbits in semi-natural environment, *Oryctolagus cuniculus*, Rödel et al. 2006; wild-type rats, *Rattus norvegicus*, Sgoifo et al. 1996; Adelie penguins, *Pygoscelis adeliae*, Cockrem 2007). However, the relationships between suites of correlated behaviours, rather than single personality traits, and hormonal levels, have rarely been studied in unselected/free-ranging animals. Such studies might allow the formulation of more realistic hypothesis than studies in selected laboratory animals, especially when social behaviours related to personality are investigated. Social embedding may modulate the behavioural expression of personality and neuroendocrinological processes (Kralj-Fišer et al. 2007).

Following the definition of avian personality by Groothuis and Carere (2005), in a previous study (Kralj-Fišer et al. 2007) we searched for repeatable and consistent inter-individual differences in behaviours and physiological characteristics in greylag goose males (ganders, *Anser anser*) belonging to a free-roaming flock of approximately 170 individuals with complex social relationships (Weiß et al. 2008). Results suggested that agonistic and

affiliative behaviours and vigilance and boldness (resistance during handling, Réale et al. 2007) may be reliable indicators of goose personality (Kralj-Fišer et al. 2007). Furthermore, individual differences in corticosterone and testosterone modulation showed strong temporal and/or cross-context consistency (Kralj-Fišer et al. 2007). This implies that corticosterone and, possibly, testosterone modulation may physiologically constrain individual behavioural plasticity and may be contingent with the behavioural correlates. Moreover, consistent inter-individual differences in sympathico–adrenergic activity, represented by heart rate (HR), may be related to goose personalities (Wascher et al. 2008).

In these ganders, it remains to be tested whether and how single behavioural traits correlate with each other and thus indeed form personality dimensions. Because we looked for relationships between behaviours that have already been shown to form part of personality in other animal species, this could add to knowledge about the existence of fundamental axes of personality across species (Gosling 2001). Because we found limited plasticity in measured physiological characteristics, we further asked whether personality dimensions were related to potentially underlying physiological characteristics, such as HR, excreted baseline and stress-induced immuno-reactive corticosterone (BM), and testosterone metabolite (TM) levels, which could provide a proximate explanation for why certain behaviours are correlated.

The behavioural and physiological correlates in our ganders may differ from correlations found in laboratory studies because of modulatory factors of the social hierarchy, i.e. cost and benefit of current social status and social support (DeVries et al. 2003; Scheiber et al. 2005a). Therefore, we also explored the relationships between dominance hierarchy, behaviours, and physiology. Finally, behavioural phenotypes may be linked to growth and body size and may vary according to sex and age (Budaev et al. 1999; Rochette et al. 2001; Sinn and Moltschanowskyj 2005). Thus, we also tested the relationships between personality, age and body size measures.

## Materials and methods

### Study animals

In 1973, a non-migratory flock of greylag geese was established in the valley of the river Alm in Upper Austria by the late Konrad Lorenz (Kotrschal et al. 2006; Lorenz 1988). Life-history data of all flock members have been recorded ever since (Hemetsberger 2001). Geese are unrestrained and freely roam the valley between the Konrad Lorenz Research Station (KLF) and a lake 10 km to the

south, where they roost at night. Geese breed in the valley every year, either at natural nest sites or in breeding boxes provided by the KLF. About 30% of the geese are hand-raised under near-natural conditions and are fully integrated into the flock. Up to 10% of the adult flock members are lost to natural predators every year (Kotrschal et al. 1992). Geese are provided with supplemental food on the meadows in front of the research station, year round. At the time of data collection the flock consisted of approximately 170 individuals. Individuals are marked with coloured leg bands and are habituated to the close presence of humans, which usually does not affect their BM levels or their HR (Wascher et al., submitted for publication). We tested ten male greylag geese, four of which were fitted with internal heart-rate transmitters. The subjects were randomly selected out of all heterosexually paired males without offspring. Focal males were  $4.7 \pm 2.5$  (mean  $\pm$  SD) years of age.

All parts of the study met the demands of Austrian animal welfare legislation and ASAB guidelines. The implantation of heart-rate transmitters was approved by the Austrian government under animal experimental license (6268.210/41-BRGT/2003). At the time of data collection, five individuals had been fitted with heart-rate transmitters but in one the transmitter had stopped working.

#### Data collection

The data set for this study partly overlaps with that in Kralj-Fišer et al. (2007), with additional data on males' heart-rate frequencies, dominance rank, body size measures, and age. Ganders were observed during handling, low-density feeding, high-density feeding, low-density post-feeding situation, and rest. High-density feeding and, particularly, the low-density post-feeding situation might not be appropriate for studying goose personality (Kralj-Fišer et al. 2007), and were therefore not included in our correlational analyses. In high-density feeding a goose might be in the middle of the dense flock, with little chance of escaping from aggressive individuals, or at the edge, where it could quickly retreat. Different experience of the threat might be particularly reflected in heart rate and corticosterone levels. In the post-feeding situation however, geese had no common challenge and were most probably in different motivational states.

For this study we took data from a handling test, a low-density feeding situation, and rest. In the handling tests, a focal gander was hand-captured, i.e. picked up avoiding a chase, and held tightly for 5 min. During this time, we recorded the duration of struggling using a stop watch. After 5 min, the gander was released into the flock. Duration of struggling has previously been shown to reflect the level of an individual's boldness (Réale et al. 2007).

In the low-density feeding situation, food pellets were spread widely over an area of approximately 160 m<sup>2</sup>. During this time, we recorded frequencies of agonistic interactions, i.e. aggressive behaviours (sum of threats, pecks, chases, beak ups), retreats (sum of retreats, escapes), received agonistic interactions (sum of being threatened, being pecked, being chased), and frequencies of vigilance behaviours (sum of head ups, extreme head ups). Behavioural observations started at the beginning of the morning feeding and lasted until the focal gander left the feeding area. Data were collected using the continuous focal animal recording method (Martin and Bateson 1993) by means of a laptop with Observer software (Noldus). The ethogram was based on the description of behavioural patterns provided by Lorenz (1988).

In the resting situation, approximately from 0930 to 1130 hours and from 1500 to 1600 hours, we simultaneously observed proximity to the mate and sociability of the focal males. The level of mutual spatial proximity between individuals may reflect the strength of social bonding among them (Hinde and Atkinson 1970). According to Lorenz (1988) this is also true for greylag geese. Therefore, we defined sociability as the average number of neighbouring geese resting in close distance (up to 2 m), excluding the female partner. Proximity to the mate was measured as the percentage of records spent with the female partner in close distance (up to 2 m). Data were recorded every 3 min. Each individual was observed on four different days, twice in the morning and twice in the afternoon. Data did not differ statistically between morning and afternoon. An individual's data were summed and expressed per unit of observation time.

The measurements were repeated three times for handling and feeding situations and four times in the resting situations (for details see Kralj-Fišer et al. 2007, p. 3). For this study, however, we took data from the first repeat only, i.e. from non-breeding season (late August, September). The other repeats were excluded from further analyses because of habituation to consequent handling trials (Kralj-Fišer et al. 2007). Besides, the influence of weather and temperature on hormonal levels was probably the lowest in the first repeat at the beginning of autumn, when the weather was fairly stable (Frigerio et al. 2004).

Dominance rank was monitored independently by one of us (B.M.W.) in the same time period as test situations were conducted. It has been shown that, in geese, the family and pair rank is determined by the gander. Dominance rank of a gander was measured as the percentage of agonistic interactions won. An agonistic interaction was defined as an encounter between two geese, in which one of them evoked retreat response from the opponent. The withdrawing goose was considered the loser of the interaction, the goose which evoked the withdrawal was considered the winner.

### Heart rate telemetry

Four focal ganders were fitted with fully implanted sensor-transmitter packages with internal antennas and a battery lifetime of 18 months. The weight of the implanted equipment, 60 g, was approximately of 2.5% of body weight even in the lightest individuals. The electronic packages measured  $60 \times 30 \times 11$  mm, were embedded in epoxy resin, and were implanted into the abdominal cavity, using non-absorbable polyester mesh for intra-peritoneal fixation (Walzer et al. 2000). Twenty-four hours after implantation the geese were released and returned to the flock. After full recovery, 2–7 days after the surgery, the implanted geese could not be distinguished from non-implanted ones in their appearance or behaviour. Details of HR telemetry are given by Wascher et al. (2008). HR was recorded along the same time axis as behaviours during feeding. We calculated the mean HR frequency per observation. Individual differences in mean HR during feeding are highly repeatable over time ( $r = 0.841$ ,  $N = 4$ ,  $P = 0.001$ ), implying that HR may be related to goose individuality also. We also calculated the mean HR during aggressive interactions (Wascher et al. 2008). An increase of HR during such interactions was calculated as mean HR during aggressive interactions minus mean HR during feeding.

### Faecal sampling and hormone analysis

In geese, faecal samples are an integrated, proportional record of plasma glucocorticosterone and testosterone levels 30–180 min before defecation (Scheiber et al. 2005b). We collected faecal samples after handling and after feeding. We observed only one individual per test situation. The focal goose was followed (from some distance) after the test situation and observed without interruption for 3 h. In this time every dropping was collected in a separate Eppendorf tube. To avoid the effect of diurnal variation and the endogenous corticosterone early morning peak (Schütz et al. 1997), faecal samples were collected only during late morning hours after feeding. Handling could only be performed opportunistically. Additionally, we sampled “matched control faeces” for 3 h the next day, at the time of day matching the time of previous handling. Faecal samples were frozen at  $-20^{\circ}\text{C}$  within 1 h after their collection.

Hormone levels in the faecal samples were analysed using enzyme immuno-assay (EIA) as described by Kralj-Fišer et al. (2007). An individual's BM and TM levels in a given situation were assessed by modelling linearly the cumulative amount of hormone excreted in successive droppings from the stimulating event to 3 h thereafter. The overall excretion level of faecal BM and

TM over time was estimated as the slope of the cumulative regression line ( $k$ ). Modulation of hormonal excretion in response to handling, i.e. stress-induced hormonal level, was estimated as the difference between the slope of a regression line in challenge ( $k1$ ) and that of a regression line in the matched control ( $k2$ ), calculated as  $k1$  divided by  $k2$  (for details see Kralj-Fišer et al. 2007). Individual baseline BM, stress-induced BM, and TM levels were repeatable over time and/or consistent across situations, and were here considered as an individual's characteristics (Kralj-Fišer et al. 2007).

### Measures of body size

We took body mass and tarsus length of each individual at the end of the handling experiments. Tarsus length is regarded as a structural measure reflecting skeletal size (Senar and Pascual 1997). One of the focal ganders could not be caught for measuring.

### Data analysis

A major concern that arises during studies which attempt to find suites of correlated behaviours is the large number of correlation statistics that are computed, increasing the possibility that significant correlation will be detected by chance alone (Type I error). A solution to this problem is to perform multivariate statistics on the entire dataset, and then determine whether behaviours load on the same factor, which would suggest that they are correlated with each other (Bell 2007). The same approach has been used in personality studies of humans, producing five major factors or axes of personality variation (the “Big Five”, McCrae and Costa 1999). We examined correlates of behaviours that were already shown to be part of personality in our ganders, i.e. boldness (time of struggling during first handling), agonistic behaviours, vigilance, proximity to the mate, and sociability (Kralj-Fišer et al. 2007), by principal-components analysis (PCA). Behaviours which load on the same factor are correlated to each other, and represent a personality dimension. To obtain the same measurement scale and for easier interpretation of the factor scores (Field 2005), data were rank-transformed. To estimate the relevant number of factors to extract we used Kaiser's eigenvalue-one rule and the scree test. In accordance with Pedhazur and Schmelkin (1991) both varimax and oblimin rotation were performed (Tabachnik and Fidell 1996; e.g. Gosling 1998). The solutions of both rotations were very similar. Here we present the solution of varimax rotation. An individual's scoring on the extracted factor, as an underlying measure for a suite of correlated behaviours, was estimated by the Anderson–Rubin method (Field 2005). The PCA determinant of the correlation matrix

**Table 1** Factor loadings from PCA

	Factor	
	1	2
Retreat	−0.935	0.005
Aggression	<b>0.868</b>	0.354
Received agonistic interactions	−0.849	−0.008
Proximity to the mate	<b>0.805</b>	−0.409
Boldness (struggling)	<b>0.557</b>	0.055
Vigilance	<b>0.500</b>	0.353
Sociability	0.001	<b>0.966</b>

Factor loadings of 0.50 or above are marked in bold

exceeded 0.0001, confirming there was no multicollinearity or singularity in the data subjected to PCA. Measures of sampling adequacy indicated that the correlation matrix was appropriate for PCA (Kaiser–Meyer–Olkin measure of sampling adequacy = 0.51, Bartlett’s test of sphericity  $\chi^2 = 34.29$ ,  $P = 0.034$ ).

We used Spearman’s correlation to test for relationships between the individual scores for each factor extracted from the PCA and hormonal levels, HR measures, dominance rank, age, and measures of body size.

We did not apply Bonferroni adjustments, because in tests on a small sample size the Bonferroni procedure reduces power, increasing the Type II error to unacceptable levels without improving the Type I error significantly (Nakagawa 2004). Data were analysed using the SPSS 13.0.1 statistical package. The results of all analyses are considered significant at the two-tailed probability of 0.05 or lower.

**Results**

**Behavioural correlates**

Principal-components analysis identified two primary factors with Eigenvalues greater than 1 that together explained 70.2% of total variance (first factor 51.1%, second factor 19.1%). Any correlation of 0.5 or above is regarded as relevant for the variable loading on each factor. Individual scores on factors 1 and 2 are further referred to as “aggressiveness” and “sociability”, respectively. In the first factor, i.e. “aggressiveness”, loadings higher than 0.5 were found for aggression, proximity to the mate, boldness, and vigilance on one end of the axis, and measures of retreats and received agonistic interactions on the other end of the axis. The second factor, i.e. “sociability”, had loadings higher than 0.5 for sociability (Table 1).

**Table 2** Spearman’s correlations ( $r_s$ ) between individuals’ scoring on extracted PCA factors and individuals’ HR ( $N = 4$ ) and hormonal levels ( $N = 10$ )

	“Aggressiveness”	“Sociability”
<b>BM response</b>		
$r_s$	<b>0.782</b>	−0.127
$P$	<b>0.008</b>	0.726
<b>TM response</b>		
$r_s$	0.321	−0.394
$P$	0.365	0.260
<b>Baseline BM</b>		
$r_s$	−0.503	−0.212
$P$	0.138	0.556
<b>Baseline TM</b>		
$r_s$	−0.188	0.503
$P$	0.603	0.138
<b>Baseline HR</b>		
$r_s$	0.400	0.000
$P$	0.600	1.000
<b>Increase in HR during aggression</b>		
$r_s$	<b>1.000</b>	n.a.
$P$	<b>&lt;0.001</b>	n.a.

Significant results ( $P < 0.05$ ) are marked in bold

HR heart rate, BM excreted immuno-reactive corticosterone metabolites, TM excreted immuno-reactive testosterone metabolites

**Table 3** Spearman’s correlations ( $r_s$ ) between “aggressiveness”, “sociability”, age ( $N = 10$ ), and measures of body size ( $N = 9$ )

		“Aggressiveness”	“Sociability”
Age	$r_s$	−0.529	−0.082
	$P$	0.116	0.822
Tarsus length	$r_s$	−0.109	−0.059
	$P$	0.781	0.881
Body mass	$r_s$	0.000	−0.050
	$P$	1.000	0.898

**Personality and physiological characteristics**

The increase of heart rate during aggressive interactions ( $\Delta$ HR) and the stress-induced BM levels correlated positively with “aggressiveness” (Table 2), but not with “sociability” (Table 2). However, none of the factor scores correlated significantly with baseline HR,  $\Delta$ HR, baseline BM, baseline TM, or stress-induced TM levels (Table 2).

*Personality, dominance, age, and measures of body size*

Individual “aggressiveness” scores were positively related to the dominance rank of an individual (Table 4), but we

**Table 4** Spearman's correlations ( $r_s$ ) between individuals' dominance rank order and their scoring on extracted factors pointed out by the PCA, i.e. "aggressiveness" and "sociability", BM, TM, and HR

	Dominance rank
<b>"Aggressiveness"</b>	
$r_s$	0.709
$P$	0.022
<b>"Sociability"</b>	
$r_s$	-0.067
$P$	0.855
<b>BM response</b>	
$r_s$	0.358
$P$	0.310
<b>TM response</b>	
$r_s$	0.333
$P$	0.347
<b>Baseline BM</b>	
$r_s$	-0.273
$P$	0.446
<b>Baseline TM</b>	
$r_s$	-0.139
$P$	0.701
<b>Baseline HR</b>	
$r_s$	0.400
$P$	0.600
<b>Increase in HR during aggression</b>	
$r_s$	1.000
$P$	<0.001

found no significant correlations between factors' scores and age or measures of body size (Tables 3, 4).

## Discussion

Principal-components analysis performed on relevant behavioural traits (Kralj-Fišer et al. 2007) suggested two factors that reflect "aggressiveness" and "sociability" as an independent personality axis in free-living, socially embedded greylag ganders. "Sociability" has been found to be an independent personality dimension in several other highly social species (chimpanzee, *Pan troglodytes*, Dutton et al. 1997; spotted hyena, *Crocuta crocuta*, Gosling 1998; pig, Forkman et al. 1995). In geese, sociability did not correlate with any of selected behaviours, and it is thus uncertain whether or not it represents personality dimension.

The "aggressiveness" dimension combined measures of aggression, boldness, vigilance, and proximity to the mate on one end of the axis, and measures of retreats and received agonistic interactions on the other end of the axis.

This resembles the fundamental personality dimension found in a variety of other species (Gosling and John 1999). The relationships between aggression and other traits parallels the behavioural correlates of coping styles, where proactive individuals are also aggressive, active in response to challenge and dominant in the group (Groothuis and Carere 2005). Similarly to our results, levels of aggression and boldness correlate with each other in selected lines of rodents (Koolhaas et al. 2001) and pigs (Hessing et al. 1993). Vigilance, which also loads on "aggressiveness", has rarely been studied as a part of personality. During feeding, aggressive ganders were more vigilant than non-aggressive ganders (personal observation). Unlike in greylag ganders, in spotted hyenas vigilance, together with activity, excitability, and nervousness, comprises an "excitability dimension" (Gosling 1998).

Another behavioural trait loading on "aggressiveness" was a gander's affiliative tendency towards his mate. Aggressive males spent more time in close vicinity to their mates than less aggressive ones. Aggression and proximity to the mate could correlate because of the affiliative tendency of the female mate, because a female of an aggressive (high-ranking, dominant) gander may be more prone to closely follow her mate, because she enjoys the benefits and protection of his higher social rank. One could argue that proximity to the mate, expression of agonistic behaviours, vigilance, and sociability might all be affected by the other individuals in the group rather than personality itself. Although we cannot exclude this possibility, high repeatability of behavioural traits through time and across different situations suggests limited behavioural plasticity in varying social and non-social environments and their relationship with an individual's personality.

Our study also searched for potential correlates between personality dimensions, physiology, and dominance (functional trait, Réale et al. 2007) in ganders. A positive correlation between the "aggressiveness" and dominance rank implies that the more aggressive, the bolder, the more vigilant, and the more mate-attached the males were, the higher was the dominance rank they achieved. The functional explanation for the correlates in "aggressiveness" proposes that this combination of traits might be favoured by selection. This is not surprising, because aggressive individuals attain higher dominance rank, have better access to food and mates, and consequently higher fitness. Furthermore, the more offspring a gander has, the higher it is in dominance rank and the more social support it receives from its family members (Scheiber et al. 2005a, Weiß et al. 2008). Thereby, offspring enjoy the same dominance rank as their father and may attain higher fitness also. However, it was expected that a more aggressive gander will most likely have a higher dominance rank. Nevertheless, a dominance rank also depends on how often

an animal is attacked, so being aggressive, alone, is not sufficient to make a high dominance rank.

The correlations between aggression, subordination, boldness, vigilance, and mate-attachment propose that these behaviours may have common genetic or neuroendocrine mechanisms. Such mechanisms have the potential to affect not just one behaviour but entire suites (Sih et al. 2004). The “aggressiveness” dimension was related to stress-induced BM levels to a considerable degree, i.e. relative change in BM in a stressful situation compared with baseline BM. This implies that aggression, subordination, boldness, vigilance, and proximity to the mate may all have their common proximate foundation in corticosterone modulation. However, the positive correlation between the “aggressiveness” and stress-induced BM levels contrasts with results from studies of coping styles (Carere et al. 2003; Koolhaas et al. 2001), where more aggressive individuals had lower corticosterone reactivity than the less aggressive ones. Similar to studies of coping style, baseline BM negatively correlated with a gander’s aggression as a single behavioural trait ( $r = -0.7$ ,  $N = 10$ ,  $P = 0.025$ ). The difference between the results of stress-induced corticosterone levels and “aggressiveness” relationships in our ganders and those from studies of coping style may be explained by modulatory factors of the dominance hierarchy. Social rank and differences in corticosterone levels are often related with costs of acquiring and maintaining dominance status (Kotrschal et al. 1998). Standard situations when baseline BM was measured may be more stressful for low-ranking (non-aggressive) ganders, whereas certain challenges may be more demanding for high-ranking (aggressive) males. In particular handling, when a male is taken from his social environment, might be threatening his rank position. However, our results on corticosterone levels and dominance rank correlation do not support this explanation.

Nevertheless, these results are in accordance with study in the lizard *Anolis carolinensis*, in which restraint stress and social stress evoked higher corticosterone responses in aggressive than in non-aggressive males (Summers et al. 2005, p. 23). This study suggests that short-term corticosterone elevation promotes aggressive and active responses in the near future, whereas chronic elevation inhibits aggression and promotes submissive behaviour (Summers et al. 2005). The latter may explain the mismatch in relationships between aggression and corticosterone modulation between studies.

The other physiological process related to “aggressiveness” may be modulation of the sympathetic nervous system (Koolhaas et al. 2001). Even though heart rate showed individuality in geese (Wascher et al. 2008, this paper), we found no significant correlation between mean HR and personality. The largest correlation powers were

below the desired 0.8, probably because the sample size was too small. However, a more detailed analysis revealed that the more aggressive, the bolder, the more vigilant, and the more mate-attached were the males, the more they increased their HR during aggressive interactions. The modulation of HR may thus be another underlying mechanism of the “aggressiveness” dimension, which is in agreement with results from studies of coping styles (Koolhaas et al. 2001). In geese however, this should be further examined on a larger number of individuals.

We conclude that ganders’ individual behavioural tendencies may be summarized as “aggressiveness” and “sociability”. “Aggressiveness” was positively related with dominance, suggesting functional links between agonistic behaviours, boldness, vigilance, and spatial proximity to mate. Personality traits related to “aggressiveness” are evidently linked with BM management and changes in the sympathetic nervous system.

**Acknowledgments** We thank Bianca Brantner, Didone Frigerio, Josef Hemetsberger, Michel Kalas, Margit Kimbauer, Violetta Pilorz, and Isabella Scheiber for help in the experimental part of the study; Erich Moestl for developing the indispensable antibodies for EIA, for letting us use them, and for discussions; Anna Aschauer and Anna Schöbitz for analysis of faecal samples; Cene Fišer for discussions on the topics; and Matjaž Kuntner and two anonymous referees for helpful comments on the manuscript. The project was funded by FWF project 15766-B03 to K. Kotrschal. S. Kralj-Fišer was supported by a Grant from the Fürst Dietrichstein’sche Stiftung and the Slovenian Research Agency (ARRS Grant 1000-06-310141 to M. Kuntner). Permanent support came from the “Verein der Förderer der Konrad Lorenz Forschungsstelle” and the “Herzog von Cumberland Stiftung”.

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