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1 The interaction between behavioural traits and demographic and management factors in
2 German Shepherd dogs

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23 Abstract

24 As companion animals, a dog's lifestyle is mainly determined by its owner. Discrepancies between
25 the dog's preferences and the owner's lifestyle might lead to the occurrence of unwanted behaviours
26 that affect both the owner-dog relationship and the dog's welfare. The aim of this study was to
27 identify behavioural traits that are characteristic of German Shepherd dogs (GSDs), and to analyse the
28 relation between behavioural traits and demographic and management factors. Dog owners from the
29 UK and Sweden were asked to complete two surveys, the established C-BARQ behavioural survey
30 and a lifestyle survey developed for the study. A principal component analysis was applied to
31 determine behavioural components for GSDs. Fifteen components were found to sufficiently explain
32 the variance in the responses to C-BARQ, with the components Stranger-directed aggression and
33 Dog-directed aggression explaining the greatest proportion of the variance in the data (12% and 10%,
34 respectively). Linear models were then applied to assess the relationship between behaviour
35 components and lifestyle factors using backward elimination to identify the model that best predicted
36 the behaviour component. The cohort (UK or Sweden) and the age of the dog were associated with
37 the highest number of behaviour components. This study showed that various demographic and
38 management factors were associated with the expression of behavioural traits in GSDs. Results from
39 this analyses may help to understand the interaction between the expression of external factors and
40 dog behavioural traits and thus, improve the well-being of dogs and owners by reducing problem
41 behaviours.

42

43 **Keywords:** C-BARQ; behaviour components; lifestyle; working dog

44

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47 Government.

48 1 Introduction

49 Extensive morphological and behavioural variability exists in purebred dogs, making certain breeds
50 more suitable for specific tasks such as herding, guarding or hunting, while others are more suited as
51 pets (Galibert et al., 2011; Mehrkam and Wynne, 2014). However, breed popularity analyses show
52 that the dog's appearance is a more important factor for breed acquisition in pet dogs than
53 functionality, behavioural traits or compatibility with the owner's lifestyle (Ghirlanda et al., 2013). A
54 genetic predisposition to express particular patterns of behaviour together with unfavourable lifestyle
55 factors may cause unwanted behaviours (e.g. aggression towards people, separation anxiety) that can
56 have negative consequences for both owner (Casey et al., 2014) and dog (Rooney and Bradshaw,
57 2014; Roth et al., 2016) and in some cases lead to relinquishment of affected dogs to animal shelters
58 or other homes (Cannas et al., 2017; Salman et al., 2000).

59 To address this issue, various studies have attempted to identify risk factors for unwanted behaviours
60 by analysing the association between demographic factors (sex, neuter status, shape, litter size and
61 weaning age) and management factors (training methods, housing and human contact) with dog
62 behaviour (Blackwell et al., 2008; Casey et al., 2014; Deldalle and Gaunet, 2014; Haverbeke et al.,
63 2008; McGreevy et al., 2013; Rooney and Cowan, 2011; Serpell and Duffy, 2016; Tiira and Lohi,
64 2015). Most of these studies concentrated either on single factors or multiple factors, but just one
65 specific component of behaviour (e.g. aggression, fear). Lofgren et al. (2014) conducted a more
66 comprehensive study on the interaction between multiple behavioural traits and a range of
67 demographic and management factors in Labrador Retrievers. Results from that study highlighted the
68 strong association between behaviour and management factors and suggested the value of
69 investigating these factors in more detail and in additional breeds.

70 The German Shepherd dog (GSD) is one of the most popular dog breeds worldwide and is used as
71 both pet and working dog. However, a drop in the UK GSD population has been observed in the last
72 years and aggressive behaviour has been identified as one of the possible causes for the breed's
73 diminishing popularity (O'Neill et al., 2017). Furthermore, the observation was made that about 30%
74 of GSDs bred for the Swedish armed forces that were raised in foster families had to be re-homed to

75 another foster home at least once during their first 18 months of life (Wilsson, 2016). High scores for
76 'Confidence' and 'Engagement' temperament traits were identified as major risk factors for re-
77 homing. A better understanding of the relationship between demographic and management factors
78 and the expression of behavioural traits may help to reduce behaviour problems in this breed and in
79 pet dogs more generally.

80 The present study describes behavioural traits in GSDs using the Canine Behaviour and Research
81 Questionnaire (C-BARQ) (Hsu and Serpell, 2003), which has been shown to successfully characterize
82 dog behaviour across breeds and countries (reviewed in Wiener and Haskell, 2016). We then further
83 developed the approach of Lofgren et al. (2014) by developing a survey that assessed demographic
84 and management factors in more detail and used it to investigate the relation between these factors
85 and behavioural traits in GSDs.

86 2 Material and methods

87 2.1 Dogs

88 This study was conducted on GSDs from the UK and Sweden. To acquire participants for the UK
89 cohort, the link to the online questionnaires was sent via email by the UK Kennel Club (KC) to all
90 GSDs registered with the KC that were at least two years old. Additionally, GSD owners were also
91 approached at dog shows and via breed clubs. Participating GSDs from the UK cohort were primarily
92 pet dogs. All GSDs from the Swedish cohort were bred within the breeding program of the Swedish
93 Armed Forces (SAF) with the purpose of becoming working dogs. Briefly, puppies were raised at the
94 SAF, weaned at the age of 8 weeks and then fostered by members of the Swedish public (Wilsson and
95 Sinn, 2012). After a behaviour test at the age of 15-18 months, dogs started working with the SAF,
96 Swedish Police or other authorities or companies, and/or were selected as breeding animals, whereas
97 others were kept as companion animals. For the Swedish cohort, owners, trainers or handlers of GSDs
98 bred within the breeding program of the SAF were invited via email or letter to participate in the
99 study.

100

101 2.2 Surveys

102 The C-BARQ consists of 101 questions related to (1) training and obedience, (2) aggression, (3) fear
103 and anxiety, (4) separation-related behaviour, (5) excitability, (6) attachment and attention seeking,
104 and (7) miscellaneous behaviours, e.g., chasing, urination (Duffy and Serpell, 2012). The initial C-
105 BARQ was extended by 15 further questions to assess the dog's playfulness (Svartberg, 2005) and 21
106 of the miscellaneous C-BARQ questions were removed (Arvelius et al., 2014), leading finally to 95
107 questions. Responses were recorded on a 0-4 scale, with higher scores indicating increasing intensity
108 of the expressed behaviour. A Swedish version of C-BARQ that had been translated and tested on
109 Swedish dog owners previously (Svartberg, 2005) was used for the Swedish cohort.

110 Based on the results of our previous study (Lofgren et al., 2014), a second survey was developed
111 (termed the 'lifestyle survey') to assess demographic and management factors of the dogs. The
112 lifestyle survey comprised questions concerning demographic factors of the dog (e.g., sex, neuter
113 status, age), its living situation (number of children, adults and other animals living with the dog,
114 where the dog is housed) and its management (puppy socialisation, exercises and stimulation,
115 training, activities). Preliminary testing was conducted for the lifestyle survey to ensure
116 comprehensibility and clarity of the questions. The lifestyle survey was also translated into Swedish
117 for use in the Swedish cohort. The English version of the lifestyle survey for the UK dogs is provided
118 in the supplemental material (Supplement 1).

119 2.3 Quality control of survey data

120 The C-BARQ and the lifestyle survey were completed for 1,041 dogs (UK = 426, Sweden = 615) that
121 met two criteria: registered with the KC (either UK or Swedish) and at least 2 years old. C-BARQ
122 allows the option "not observed/not applicable" for behaviours that could not be observed. Those
123 answers were handled as missing values. There were 299 dogs that had no missing values across all
124 items, whereas 742 had one or more missing values.

125 The response rate for each C-BARQ question was calculated. Based on Hsu and Serpell (2003),
126 questions with a response rate < 85% were excluded, which was the case for four questions related to

127 aggressive behaviour between dogs in the same household and thus were not applicable for owners
128 with only one dog.

129 Lifestyle survey responses were also checked for completeness. Factors with excessive missing
130 responses were excluded from subsequent analyses. Factors excluded were the dog's role as
131 "companion" (no translation into Swedish available), age of neutering, coat length, whether the dog
132 would be used for breeding, litter size (reliable data available for the Swedish cohort only), the
133 working dog status (missing for 115 Swedish dogs), the type of working dog (not available for non-
134 working dogs) and the puppy socialisation status (unknown for 235 dogs). In a subsequent analysis,
135 several factors of particular interest that were excluded from the full data set due to a high number of
136 missing responses (litter size, working dog status and the level of socialisation as a puppy) were
137 considered in the statistical model using reduced data sets (only including dogs with complete
138 responses for the relevant factor).

139 2.4 Characterisation of GSD behavioural traits

140 Responses from the C-BARQ survey were used to define the dog's behaviour in two ways: (I) by
141 calculating behavioural components specifically for the GSD (GSD_{Comp}) and (II) by calculating scores
142 for general behaviour components (Dog_{Comp}). The latter is a set of components that has been defined
143 for and used in studies of multiple dog breeds by Duffy and Serpell (2012) and also includes the three
144 play-related traits Dog directed interest, Human-directed play interest and Stranger-directed interest
145 defined by Svartberg (2005). While GSD_{Comp} were used in the subsequent analyses of the interaction
146 between behavioural traits and demographic and management factors, we also calculated the Dog_{Comp}
147 to enable behavioural traits comparisons with other studies.

148 To calculate the GSD_{Comp} , a principal component analysis (PCA) was applied to the data to condense
149 the 95 questions to a smaller number of components. GSD-specific components (principal
150 components) were calculated for two main reasons: the original C-BARQ survey was extended with
151 the inclusion of 15 playfulness-related questions and the average scores for the Dog_{Comp} showed non-
152 normal distributions that could lead to difficulties in subsequent analyses. Prior to running the PCA,

153 several procedures (Cattell's scree-test, Horn's Parallel test and the Very Simple Structure (VSS)
154 criterion) were applied and implemented using the R package 'psych' to identify the optimal number
155 of components that capture the important information (Abdi and Williams, 2010), which gave a value
156 of 15 for all tests. The PCA was then run for 15 principal components, followed by a varimax
157 (orthogonal) rotation (for more information see Abdi and Williams, 2010). Missing values in the data
158 set were replaced by the median value. Referring to Comrey and Lee (1992), questions that had
159 loadings $> |0.55|$ were considered as 'relevant' for the particular component and were used for
160 labelling the components. Furthermore, this threshold was used for a subsequent filtering step: for
161 each component the percentage of missing values of relevant items was calculated per dog. As
162 suggested by Duffy and Serpell (2012), dogs with missing values for $>20\%$ of the relevant questions
163 per component were excluded from this component. The dog's scores for the 15 components were
164 considered as behaviour phenotypes in the following analysis (GSD_{Comp}).

165 To calculate the Dog_{Comp} , the average score on a scale from 0 to 4 was calculated across questions for
166 16 previously-defined traits (trainability, stranger-directed aggression, owner-directed aggression,
167 stranger-directed fear, non-social fear, dog-directed aggression, dog-directed fear, touch sensitivity,
168 separation-related behaviour, excitability, attachment/attention seeking, chasing, energy level, dog
169 directed interest, human-directed play interest and stranger-directed interest). The component dog-
170 rivalry was excluded due to an excess of missing records (refers to multiple dogs living in the same
171 household). As described above, if $>20\%$ of the records for questions in a component were missing,
172 this component was not calculated for the particular dog (Duffy and Serpell, 2012).

173 2.5 Characterisation of demographic and management factors

174 Some demographic and management factors were transformed and summarized prior to statistical
175 analysis to simplify the analyses and to reduce the number of correlated factors considered in the
176 models. Numbers of animals and dogs in the household were transformed into binary factors
177 (presence of other dogs and animals = 1, absence = 0). The commands a dog was trained for were
178 summarized into a numerical factor "Number of commands". The interaction between sex and neuter

179 status has been found to be associated with behaviour in dogs (Casey et al., 2014) and thus, this factor
180 was also considered in the statistical analysis.

181 To avoid overfitting of the factors in the statistical analysis, the options for the four multiple choice
182 questions in the lifestyle survey were condensed using PCA. These included the following four
183 questions: “Role” (How do you see your dog?); “Comp” (Which of the following competitions has
184 your dog participated in?); “Train” (Which of the following training methods do you use?); and “Soc”
185 (Which of the following events was your dog socialised with as a puppy?). The same PCA protocol
186 was used as for the C-BARQ items: (I) the appropriate number of components was determined, (II)
187 the PCA was run using varimax rotation and (III) factors with a loading $\geq |0.55|$ were considered as
188 relevant and used for labelling the component. The PCA suggested a number of key components
189 describing the level of puppy socialisation, the role of the dog, the competition profile and training
190 method. Further details are given in the results section below.

191 In total, 28 demographic and management factors were taken into account to analyse the full data set
192 plus three factors considered in the reduced data sets (“Working dog”, “Litter size” and “Soc_PC1”),
193 respectively. An overview of all demographic and management factors is given in Supplement 2. To
194 explore the interaction between numeric, ordinal and binary demographic and management factors,
195 Pearson (numeric-numeric), polyserial (numeric-ordinal) and polychoric (ordinal-ordinal) correlations
196 were calculated for the particular factor types as implemented in the ‘hetcor’ function in R.

197 2.6 Influence of demographic and management factors on GSD behavioural traits

198 The effect of demographic and management factors on GSD_{Comp} was analysed using linear models.
199 To identify factors associated with the behaviours, all demographic and management factors were
200 initially fitted as fixed effects (initial model) in R. Then backward elimination implemented in the
201 ‘stepAIC’ function of the R package ‘MASS’ was applied by removing one factor at a time to select
202 the model with the lowest Akaike information criterion (AIC) (final model). The variance explained
203 by the final model was calculated using the function ‘Dsquared’ in the R package ‘modEVA’ (Barbosa
204 et al. 2013). Across the 15 GSD_{Comp} , the average number of dogs included per model for the full data

205 set was 933 (range = 850-968). Sizes of the reduced data sets were: 835 (range = 756 – 868) for
206 “Working dog status”, 548 (range = 517 – 559) for “Litter size” and 728 (range = 660 – 758) for
207 “Socialisation status”.

208 3 Results

209 3.1 Characterisation of behavioural traits in GSDs

210 PCA was used to generate GSD-specific behavioural traits (GSD_{Comp}, Supplement 3). The 15
211 components (in descending order for the proportion of variance explained by the PCA) were labelled
212 according to the relevant items as “Stranger-directed aggression” (positive loadings of aggressive
213 behaviour towards strangers), “Dog-directed aggression” (positive loadings of aggressive behaviour
214 and negative loadings of playfulness towards unfamiliar dogs), “Stranger-directed fear” (positive
215 loadings of fearful behaviour towards strangers), “~~Playfulness~~Human-directed playfulness” (positive
216 loadings of playful interaction with humans), “Resource guarding” (positive loadings of owner-
217 directed aggression in regard to food or toys), “Excitability” (positive loadings of excited behaviour in
218 response to different situations), “Separation anxiety” (positive loadings of stress-related behaviour
219 when left alone), “Lack of obedience” (negative loadings of obedience-related behaviours), “Stranger-
220 directed interest” (positive loadings of friendly interaction with strangers), “Attention seeking”
221 (positive loadings of attention-seeking behaviour towards owner), “Chasing” (positive loadings of
222 chasing-related behaviours), “Non-social fear” (positive loadings of fear response to loud noise or
223 unfamiliar objects), “Dog-directed fear” (positive loadings of fearful behaviour towards unfamiliar
224 dogs), “Aversion of being stepped over” (positive loadings of fearful or aggressive response when
225 stepped over) and “Touch-sensitivity” (positive loadings of fearful behaviour when touched for
226 various treatments). Descriptive statistics for GSD_{Comp} scores are shown in Table 1.

227 The Dog_{Comp} scores (ranging from 0 to 4) were calculated for each dog (Table 2). The highest average
228 scores in GSDs were recorded for Human-directed play interest (3.15 ± 0.02 ; mean and standard
229 error), followed by Trainability (2.63 ± 0.01) and Stranger-directed interest (2.34 ± 0.04). The lowest
230 average scores were measured for Owner-directed aggression (0.08 ± 0.01), Stranger-directed fear

231 (0.15 ± 0.01) and Separation-related behaviours (0.20 ± 0.01). Touch-sensitivity had the greatest
232 number of missing records and Dog rivalry was not calculated because of >20% missing values.

233 3.2 Description of demographic and management factors

234 There were a number of differences between the UK and Swedish GSDs regarding demographic and
235 management factors (Supplement 2). The majority of UK GSDs lived together with other dogs or
236 animals, whereas Swedish dogs were primarily kept without the presence of other animals. The
237 majority of UK GSDs were neutered while the majority of Swedish GSDs were intact. Of the UK
238 GSDs, 77.4% had been used for breeding (some of the GSDs were used for breeding before neutering,
239 which accounts for the high levels of both neutered dogs and dogs used for breeding), whereas only
240 9.4% of the Swedish dogs had offspring. The Swedish dogs received more frequent training than the
241 UK dogs, but participated less often in dog shows. Because of the differences between the
242 populations, we considered analysing them separately. However, it was concluded that a single
243 analysis would give greater statistical power, and that by fitting demographic and management factors
244 and the cohort (for demographic and management factors that were not captured with the lifestyle
245 survey) we sufficiently accounted for differences in the two cohorts.

246 The PCA of the multiple choice questions in the lifestyle survey resulted in one component for “Soc”
247 (Soc_PC1), two components for “Role” (Role_PC1, Role_PC2) and “Comp” (Comp_PC1,
248 Comp_PC2), and three components for “Train” (Train_PC1, Train_PC2, Train_PC3) (described in
249 Supplement 3). Soc_PC1 is described by high loadings for all puppy socialisation options (highly
250 positive scores equate to high socialisation status of the dog); Role_PC1 is described by high loadings
251 for pet dog functions (highly positive scores equate to pet dog), Role_PC2 is described by high
252 loadings for a specific function (highly positive scores equate to co-worker and highly negative scores
253 to show dog); Comp_PC1 is described by high loadings for showing (highly positive scores equate to
254 participation in dog shows and highly negative scores to no participation in competitions), Comp_PC2
255 is described by high loadings for participation in advanced obedience competitions (highly positive
256 scores equate to advanced/ high level of obedience); Train_PC1 is described by high loadings for

257 positive reinforcement (highly positive scores equate to the use of positive reinforcement, highly
258 negative scores equate to no training), Train_PC2 is described by high loadings for
259 counterconditioning (highly positive scores equate to the use of counterconditioning) and Train_PC3
260 is described by high loadings for aversive training methods (highly positive scores equate to the use of
261 aversive methods).

262 Results for the correlation analysis between the numeric and ordinal demographic and management
263 factors are illustrated in Supplement 4. The correlations were low to moderate, with the highest
264 correlations found for “People_hh” with “Children_hh” (0.63), “F_interaction_humans” with
265 “F_interaction_dogs” (0.59), “Role_PC2” with “Comp_PC1” (-0.4), “Age.acquisition” with
266 “Soc_PC1” (-0.35), “F_training” with “Commands” (0.36) and “Commands” with “Comp_PC2”
267 (0.31).

268 3.3 Factors associated with behavioural traits in GSDs

269 Following backward elimination, the final models based on GLM explained on average 7.0% of the
270 variance in the data. The maximum of 16.9% explained variance was found for Stranger-directed
271 interest and the minimum of 1.3% explained variance for Excitability (Table 3). Out of the 15
272 GSD_{Comp}, the factors that appeared most frequently in the final models were “Cohort” and “Age” (9
273 GSD_{Comp}), “Commands”, “Dogs_hh”, “Gender*Neuter status” and “F_offlead” (7) (Table 3). As we
274 used AIC for model selection, some factors with non-significant associations with GSD_{Comp} remained
275 in the final models. However, the results presented primarily focus on demographic and management
276 factors that were present as significant associations ($p < 0.05$) in the final models.

277 3.3.1 Environment

278 Figure 1 shows the adjusted effect size of “Cohort” from the fitted final models for the nine GSD_{Comp}
279 where the factor “Cohort” appeared in the final model. For some of these traits, the effect directions
280 were “favourable” (negatively associated with problem behaviours and positively associated with
281 desired or neutral behaviours) in the UK cohort; these included lower scores for Dog-directed

282 aggression, Resource guarding, Lack of obedience, Dog-directed fear, Attention seeking and higher
283 scores for Stranger-directed interest. For other traits the effect directions were favourable in the
284 Swedish cohort, including lower scores for Stranger-directed aggression and Chasing and higher
285 scores for ~~Playfulness~~Human-directed playfulness.

286 The presence of other dogs in the household (“Dogs_hh”) had primarily a favourable association with
287 GSD_{Comp}. With at least two dogs per household, scores for Dog-directed aggression, Resource
288 guarding, Separation anxiety, Lack of obedience, Attention-seeking and Touch-sensitivity were lower
289 compared to scores for dogs in a single-dog household (Table 3). The presence of other animals in the
290 household (“Animals_hh”) was also favourably associated with GSD_{Comp}, for example with lower
291 scores for Stranger-directed fear and Chasing.

292 The living place of the dog was associated with Excitability and ~~Playfulness~~Human-directed
293 playfulness. Dogs that live primarily outdoors had the highest scores for ~~Playfulness~~Human-directed
294 playfulness but the lowest scores for Excitability (Figure 2).

295 3.3.2 Dog-related factors

296 Various demographic factors were associated with the GSD_{Comp}. While sex and neuter status did not
297 appear as main effects in the final models, the interaction between sex and neuter status appeared
298 among the factors in the final model for seven traits. Intact dogs had higher scores for Separation
299 anxiety and lower scores for Non-social fear than neutered dogs for both males and females (Figure
300 3). In contrast, other GSD_{Comp} showed inconsistent results between the sexes. Neutered male GSDs
301 had lower scores for Stranger-directed fear and ~~Playfulness~~Human-directed playfulness than intact
302 male dogs, but the opposite pattern was seen for female dogs.

303 The dog’s age was another factor occurring in the final model for several traits. With increasing age,
304 scores for Stranger-directed aggression, Stranger-directed fear, ~~Playfulness~~Human-directed
305 playfulness, Chasing, Non-social fear, and Dog-directed fear decreased while Dog-directed aggression
306 increased. An association with coat colour was detected for Chasing with sable GSDs having higher

307 scores for Chasing than dogs with other coat colours (Figure 4). Litter size, which was analysed on a
308 reduced data set, was not associated with any of the GSD_{Comp} in the final models.

309 3.3.3 Management and lifestyle

310 Participation in dog competitions (“Comp_PC1”, “Comp_PC2”) was favourably associated with some
311 of the GSD_{Comp} . Dogs participating in dog shows (high scores for “Comp_PC1”) had significantly
312 lower scores for Stranger-directed aggression and Touch sensitivity. Dogs with high scores for the
313 participation in advanced obedience competitions (“Comp_PC2”) tended to have high scores for
314 PlayfulnessHuman-directed playfulness. Likewise, the greater the number of commands a dog was
315 trained for, the higher the scores were for PlayfulnessHuman-directed playfulness, Stranger-directed
316 interest and the lower the scores were for Stranger-directed fear, Lack of obedience, Attention seeking
317 and Non-social fear. High scores for the use of dog training including aversive and dominance based
318 methods (“Train_PC3”) was associated with low scores for Dog-directed aggression, Stranger-
319 directed fear, and Aversion being stepped over.

320 Frequent interaction with humans or dogs was associated with decreased scores for aggression
321 towards the respective species and also with increased scores for Stranger-directed interest in the case
322 of frequent interaction with humans and with increased scores for Dog-directed fear in the case of
323 frequent interactions with dogs. More frequent walks were associated with higher scores for Stranger-
324 directed aggression and lower scores for Stranger-directed fear. The greater the amount of exercise the
325 dog received per day, the higher were scores for Separation anxiety and Attention seeking. More
326 frequent training and time off-lead during walks were associated with lower scores for Lack of
327 obedience and Chasing.

328 The working dog status (“Working.dog”) and the dog’s socialisation as a puppy (“Soc_PC1”) were
329 analysed on reduced data sets due to a high number of missing values. The working dog status
330 occurred twice in a final model of GSD_{Comp} : working dogs had higher scores for Excitability than non-
331 working dogs (effect: 0.16, p-value = 0.06) and lower scores for Dog-directed aggression (effect:
332 -0.16, p-value = 0.09). The factor “Soc_PC1” was accounted for in final model for seven traits. High

333 scores for socialisation as a puppy were significantly associated with lower scores for Excitability and
334 higher scores for Stranger-directed interest and Chasing.

335 4 Discussion

336 In this study, we assessed demographic and management factors and analysed their contribution to the
337 expression of behavioural traits in German Shepherd dogs (GSDs). We classified the responses given
338 in a standard dog behavioural survey (C-BARQ) into behavioural traits that are characteristic for this
339 dataset (GSD_{Comp}) and showed that various demographic and management factors are associated with
340 these GSD_{Comp} .

341 4.1 GSD specific behavioural traits

342 The PCA suggests that 15 components (principal components) can be used to characterise the
343 behaviour of GSDs. The resulting GSD_{Comp} (Supplement 2) are generally consistent with the
344 behavioural traits described in Duffy and Serpell (2012) and Svartberg (2005) (Dog_{Comp}) across many
345 breeds. Nevertheless, there are GSD_{Comp} that differed from the Dog_{Comp} : (1) C-BARQ items loading to
346 the Dog_{Comp} Owner-directed aggression are divided into two GSD_{Comp} , Resource guarding and
347 Aversion to being stepped over, and (2) the Dog_{Comp} Energy level was not identified as a GSD_{Comp} (the
348 questions associated with Energy level had loadings $< |0.55|$ for all of the GSD_{Comp}). The overlaps
349 between GSD_{Comp} and Dog_{Comp} shown in this study support the consistency of Dog_{Comp} classified by
350 Duffy and Serpell (2012), which has also been demonstrated in other studies (Berg et al., 2006; Duffy
351 et al., 2008; Nagasawa et al., 2011).

352 However, the difference between the GSD_{Comp} and Dog_{Comp} lists indicate that breed-specific
353 behavioural variation exists and that it can be identified with the C-BARQ survey. The same
354 observation was made in Lofgren et al. (2014), where based on the C-BARQ survey, the novel traits
355 Fetching and Barking tendency were identified as varying within Labrador Retrievers; these traits
356 were not shown as behaviour components in other studies.

357 Dog_{Comp} for GSDs were in accordance with scores for GSDs reported in other studies. GSDs had high
358 average scores for Trainability, medium scores for Dog-directed aggression and Stranger-directed
359 aggression and low scores for Stranger-directed fear as in previous studies (Foyer et al., 2014;
360 Ghirlanda et al., 2013).

361 4.2 Factors associated with GSD behavioural traits

362 By applying linear models to fit the relationships between GSD_{Comp} and demographic and
363 management factors, we found that various factors were associated with the behavioural traits (Table
364 3), consistent with the widely recognized theory that the expression of behaviour is influenced by the
365 environment (reviewed in Sih et al., 2004). Because a dog shares the environment and lifestyle with
366 its owner, and these can differ substantially between individuals, there are many factors with a
367 potential influence on behavioural traits. This is indicated by our results, which showed that 27 out of
368 31 factors we examined were associated with at least one of the 15 GSD_{Comp}. However, we cannot
369 infer cause and effect for many of the associations and although many factors were taken into account
370 to analyse the described behavioural traits, they still only explained a small proportion of the variance
371 observed in the GSD_{Comp} (ranging from 1.3% to 16.9%), similar to the study of Casey et al. (2014).
372 There are presumably additional factors and experiences that contribute to behavioural differences
373 between dogs, e.g. whether the resting place was a dog basket, the sofa or the owner's bed (Cannas et
374 al., 2017), the style of playful interaction with the owner (McGreevy and Masters, 2008), and even the
375 owner's personality (Dodman et al., 2018), that were not assessed in this study.

376 The origin of the dog ("Cohort") was associated with eight out of the 15 GSD_{Comp}. Different
377 management regimes or demographic characteristics between GSDs from the UK and Sweden that
378 were not assessed in the lifestyle survey may be the cause of this effect or even 'cultural' differences
379 between British and Swedish dog owners that influenced how they responded to the survey. The
380 rearing of the dogs is likely to be a critical influence affecting behavioural traits. All Swedish GSDs
381 were reared under standardized conditions and had undergone frequent handling for behaviour and
382 health assessment as puppies (described in Foyer et al., 2013) while the rearing of UK GSDs

383 depended on the respective owner. Alternatively, the breeding (i.e. genetic) background of the dogs in
384 this study may play a large role. GSDs from the UK cohort are primarily pet dogs, whereas Swedish
385 dogs were all bred in a working dog program for the Swedish Armed Forces. Moreover, 77.4% of
386 GSDs from the UK were used for breeding compared to 9.4% of breeding dogs in the Swedish cohort,
387 which further indicates differences between the two cohorts.

388 To determine the effect of the dog's role as a working dog, this factor was analysed on a reduced data
389 set. While other studies detected multiple behaviour differences between working and non-working
390 dog breeds (Eken Asp et al., 2015; Lofgren et al., 2014; Mariti et al., 2013), the working dog status
391 was only associated with a single trait (Excitability) for the within-breed comparison conducted in this
392 study. However, because the Swedish cohort encompassed dogs selected as working dogs (although
393 not all were used as working dogs) while the UK dogs were mainly pets (only 5.6% working dogs),
394 the cohort factor might partly reflect this selection and thus also account for the working vs non-
395 working status of the dogs in this study. Further genetic investigation of the two cohorts may provide
396 insight into this issue.

397 No associations with GSD_{Comp} were found for "Sex" or "Neuter status" as separate factors in
398 accordance to other studies (Blackwell et al., 2008; Casey et al., 2014). Instead, the critical factor in
399 our study was the interaction between sex and neuter status, especially for fear-related GSD_{Comp} .

400 Although the causal relationship could not be revealed with data from this study, our results and
401 findings of other studies (Duffy, 2006; Farhoody, 2010; Kaufmann, 2017) indicate that neutering may
402 increase fear and insecurity. The increase in aggressive behaviour in neutered dogs described in
403 previous studies (Kaufmann, 2017; Podberscek and Serpell, 1996) could not be tested in this study,
404 however, fear and insecurity can be the underlying driving factors for aggressive behaviour (Eken Asp
405 et al., 2015).

406 The scores for aggressive or fearful behaviours were lower with increasing age, apart from aggressive
407 behaviour towards dogs, which increased. Other studies found an association between increasing age
408 and the reduction of problem behaviours, such as fear in response to sudden noises (Åkerberg et al.,
409 2012) as well as attention-seeking and separation-anxiety (Blackwell et al., 2008), but others observed

410 an increase of aggressiveness in older dogs (Bennett and Rohlf, 2007; Casey et al., 2014; Eken Asp et
411 al., 2015). These inconsistent results indicates that over time, dogs will experience situations that alter
412 the expression of certain behaviours. With increasing age, there is a higher likelihood of unfavourable
413 individual experiences contributing to aggression or fear, but frequent training and positive
414 interactions with humans or dogs might counteract this effect.

415 Training characteristics (level, frequency and method of training) were associated with several
416 GSD_{Comp} in our study. We found that the different factors characterising the training level of a dog
417 were positively correlated with each other (Supplement 4) and that a high training level (indicated by
418 high scores for the participation in advanced obedience competitions “Comp_PC2”, a high number of
419 commands for which a dog was trained and frequent training) was primarily favourably associated
420 with unwanted behaviours. This finding is consistent with a negative correlation between obedience
421 training and the exhibition of problem behaviours and also with an improvement in obedience and
422 performance with frequent training, as described in previous studies (Alexander et al., 2011; Bennett
423 and Rohlf, 2007; Clark and Boyer, 1993; Jagoe and Serpell, 1996). Interestingly, high scores for the
424 participation in advanced obedience competitions (“Comp_PC2”) and a high number of commands
425 for which a dog was trained, were also associated with high scores for PlayfulnessHuman-directed
426 playfulness. The direction of causality between a high training level and the increased expression of
427 playfulness remains unknown, but this association suggests several possibilities. Perhaps some aspect
428 of the training experience promotes a positive emotional state in the dog, allowing playfulness to be
429 expressed more often or maybe the playful interaction itself supports better learning abilities in dogs,
430 as suggested by the study of Affenzeller et al. (2017). Another possibility is that owners choose to
431 spend more time in training activities with more playful dogs.

432 ~~Higher scores for aversive training methods (“Train_PC3”) were associated with lower scores for~~
433 ~~unwanted behaviours (Dog directed aggression, Stranger directed fear and Dog directed fear), but~~
434 ~~also with lower scores for Stranger directed interest. Higher scores for positive reinforcement based~~
435 ~~training methods (“Train_PC1” and “Train_PC2”) were associated with lower scores for Touch-~~
436 ~~sensitivity. The causal relationship between training methods and dog behaviour needs to be further~~

437 ~~investigated, as it has been reported that the use of aversive methods can affect the dog's welfare by~~
438 ~~inducing stress (Deldalle and Gaunet, 2014) and suppress the dog's performance in obedience and~~
439 ~~“protection work” exercises (Haverbeke et al., 2008), while positive reinforcement methods have been~~
440 ~~suggested to positively influence the dog's learning ability (Rooney and Cowan, 2011).~~

441 Higher levels of daily exercise were associated with higher scores for Separation anxiety and
442 Attention seeking. This is in agreement with a study by Mariti et al. (2013), which showed a trend
443 across breeds for higher attachment of search and rescue dogs to their owners compared to non-
444 working dogs. Parthasarathy and Crowell-Davis (2006) suggest that dogs that spend more time with
445 their owners in intensive activities may be more prone to show separation-anxiety than dogs that
446 spend less time in intensive activities with their owners, due to a specific attachment style of the
447 former. However, other studies showed a favourable association between the levels of daily exercise
448 and separation anxiety (Lofgren et al., 2014; Tiira and Lohi, 2015). The variance explained for
449 GSD_{Comp} Separation anxiety by the associated demographic and management factors was <3%,
450 indicating the complex nature of this trait and that there are other unmeasured factors that influence
451 the expression of separation anxiety, e.g., time left alone (Rehn and Keeling, 2011).

452 5 Conclusions

453 Multiple factors are associated with behavioural traits in dogs, but the direction of the effect differs
454 across studies (e.g. sex, neuter status) and these factors generally explain only a small amount of the
455 variation in the behaviour. Considering the influence of the dog's age on many behavioural traits in
456 this study, we conclude that individual experiences that were not captured by the lifestyle survey also
457 play an important role. However, we observed that several management factors (e.g. the frequency of
458 training, participation in dog competitions) had an overall favourable association that suggest these
459 activities may reduce the risk of undesirable behaviours. The results presented here indicate that dog
460 training rather than high levels of exercise *per se* may be key to modulating dog behaviour, indicating
461 an influence of the owner-dog bond. The extent to which behavioural differences associated with
462 cohort are due to environmental factors not accounted for in this study or genetic differences (e.g. due

463 | to selection for working characteristics) needs further investigation. For future studies on behaviour
464 | characteristics in dogs, it will be useful to agree on key environmental and demographic factors to
465 | consider in analyses. This will help in identifying consistent findings across studies and ultimately
466 | may suggest improvements for dog management.

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620 Tables

621 Table 1 Statistics for scores in behaviour characteristics calculated for German Shepherd dogs
 622 (GSD_{Comp}) using a principal component analysis to condense the C-BARQ questions.

	N	Average	SD	Median	Min	Max	Range
Stranger-directed aggression	1033	0.00	0.99	-0.24	-1.81	6.67	8.48
Dog-directed aggression	906	0.01	1.03	-0.19	-2.41	3.32	5.73
Stranger-directed fear	1018	0.01	0.99	-0.13	-2.26	7.77	10.03
<u>Playfulness</u> Human-directed <u>playfulness</u>	1031	0.00	0.99	0.22	-4.96	1.89	6.84
Resource guarding	967	0.00	1.03	-0.16	-1.24	12.33	13.57
Excitability	1038	0.00	1.00	0.02	-3.12	2.60	5.71
Separation anxiety	1010	0.00	1.00	-0.32	-1.56	9.02	10.57
Lack of obedience	1011	-0.01	1.00	-0.10	-2.33	4.61	6.93
Stranger-directed interest	985	-0.01	1.01	0.03	-2.92	2.51	5.43
Attention seeking	1003	0.01	1.00	0.05	-3.17	3.31	6.48
Chasing	966	0.01	1.02	0.00	-2.60	2.93	5.54
Non-social fear	1025	0.00	0.98	-0.29	-2.30	5.58	7.88
Dog-directed fear	1001	0.02	1.00	-0.16	-4.10	5.18	9.28
Aversion being stepped over	1029	0.00	1.00	-0.08	-1.93	15.43	17.36
Touch-sensitivity	966	0.01	0.99	-0.26	-2.75	6.44	9.19

623

624

625 Table 2 Statistics for scores in general dog behaviour characteristics (Dog_{Comp}). Individual
 626 scores were calculated as an average over a set of C-BARQ questions defined in
 627 ¹Duffy & Serpell (2012) and ²Svartberg (2005) and could range from 0 to 4.

	N	Average	SD	Median	Min	Max	Range	SE
Trainability ¹	1030	2.63	0.33	2.63	0.00	4.00	4.00	0.01
Stranger-directed aggression ¹	1033	0.45	0.52	0.30	0.00	4.00	4.00	0.02
Owner-directed aggression ¹	1020	0.08	0.23	0.00	0.00	2.75	2.75	0.01
Stranger-directed fear ¹	1003	0.15	0.40	0.00	0.00	4.00	4.00	0.01
Non-social fear ¹	1030	0.26	0.36	0.17	0.00	2.60	2.60	0.01
Dog-directed aggression ¹	1006	1.21	1.03	1.00	0.00	4.00	4.00	0.03
Dog-directed fear ¹	1001	0.41	0.70	0.00	0.00	4.00	4.00	0.02
Touch sensitivity ¹	953	0.26	0.39	0.00	0.00	3.00	3.00	0.01
Separation-related behaviours ¹	1025	0.20	0.35	0.00	0.00	2.75	2.75	0.01
Excitability ¹	1038	2.17	0.86	2.17	0.00	4.00	4.00	0.03
Attachment/ attention seeking ¹	1028	1.91	0.75	1.83	0.00	4.00	4.00	0.02
Chasing ¹	977	1.77	1.04	1.67	0.00	4.00	4.00	0.03
Energy level ¹	1028	2.32	0.99	2.50	0.00	4.00	4.00	0.03
Stranger-directed interest ²	985	2.34	1.21	2.33	0.00	4.00	4.00	0.04
Human-directed playfulness interest ²	1031	3.15	0.71	3.20	0.00	4.00	4.00	0.02
Dog-directed interest ²	961	2.01	1.04	2.00	0.00	4.00	4.00	0.03

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	PC1: Stranger-directed aggression	PC2: Dog-directed aggression	PC3: Stranger-directed fear	PC4: <u>Playfulness</u> <u>Human-directed playfulness</u>	PC5: Resource guarding	PC6: Excitability	PC7: Separation anxiety	PC8: Lack of obedience	PC9: Stranger-directed interest	PC10: Attention seeking	PC11: Chasing	PC12: Non-social fear	PC13: Dog-directed fear	PC14: Aversion being stepped over	PC15: Touch-sensitivity
Cohort (UK vs Sweden)	0.60	-0.35		-0.67	0.14			-0.28	0.68	-0.25	0.62		-0.27		
People_hh								0.04						-0.04	-0.04
Children_hh															
Dogs_hh (yes)		-0.30			-0.21		-0.14	-0.24		-0.15			0.15		-0.12
Animals_hh (yes)			-0.24						0.13		-0.30				
Living place outdoors vs indoors				0.35		-0.42									
indoors/outdoors vs indoors				0.00		-0.28									
working place vs indoors				-0.99		-0.31									
Age ³	-0.02	0.02	-0.03	-0.07	0.02				0.02		-0.03	-0.03	-0.02		
Gender															
Neuter status															
Gender*Neuter status															
Female neutered vs female intact			0.11	0.12			-0.13			0.00		0.16	-0.01	-0.08	
Male intact vs female intact			-0.03	0.18			0.12			0.20		0.07	-0.19	-0.07	
Male neutered vs female intact			-0.20	0.02			0.03			0.03		0.40	-0.01	0.29	
Coat colour															
Sable vs GSD coloured											0.21				
Black vs GSD coloured											0.09				
Other vs GSD coloured											-0.06				
Age.acquisition				-0.04					-0.04				-0.03		-0.03
Bred (yes)			-0.15								-0.26				
Shape	0.13										-0.15		-0.23		
Role_PC1	0.06						-0.05								
Role_PC2				-0.05								0.06			
Comp_PC1	-0.09													-0.06	-0.08
Comp_PC2	-0.05			0.10				-0.05				-0.05			
Commands		0.05		0.08				-0.04		-0.09	0.04	-0.04			0.05
Train_PC1														0.05	-0.08
Train_PC2															-0.07
Train_PC3		-0.08	-0.06		-0.07				-0.07					-0.08	
F_walking	0.17		-0.11				-0.14				0.11				
F_interaction_humans	-0.14								0.07						
F_interaction_dogs		-0.16		-0.04									-0.06		-0.05
F_training								-0.10	0.06		-0.06				
F_exercise					0.09		0.12			0.16					
F_offlead	-0.05				0.05	0.07	-0.05	-0.12		0.06	-0.05				
VarExp ¹	9.0	11.0	3.6	16.1	2.3	1.3	2.7	10.3	16.9	6.1	13.0	3.7	3.7	2.7	2.8

632 Significant effects (p < 0.05) are highlighted in bold

633 ¹ Variance explained by the final model

634 Figure Captions

635 **Figure 1** Effect display for the cohort in the generalised linear model fit for behaviour components.

636 The fitted values for the cohort are shown for all behaviour components were this factor appeared in
637 the final model with upper and lower confidence bounds.

638 **Figure 2** Effect display for the dog's living place in the generalised linear model fit for behaviour
639 components. The fitted values for the living place are shown for all behaviour components were this
640 factor appeared in the final model with upper and lower confidence bounds.

641 **Figure 3** Effect display for the interaction between sex and neuter status in the generalised linear
642 model fit for behaviour components. The fitted values for the interaction between sex and neuter
643 status are shown for all behaviour components were this factor appeared in the final model with upper
644 and lower confidence bounds.

645 **Figure 4** Effect display for the dog's coat colour in the generalised linear model fit for behaviour
646 components. The fitted values for the coat colour are shown for all behaviour components were this
647 factor appeared in the final model with upper and lower confidence bounds.

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649 Supplement

650 **Supplement 1** English version of the lifestyle survey

651 **Supplement 2** Description of demographic and management factors assessed with the lifestyle survey
652 that were used in the multivariate analyses. The distribution of factors is shown among the two
653 cohorts "UK" and "Sweden".

654 **Supplement 3** GSD_{Comp} generated by a principal component analysis of C-BARQ responses with the
655 questions that loaded with $\geq |0.55|$ to the 15 components. The variance explained by the component is
656 in parentheses after the component name.

657 **Supplement 4** Correlation between demographic and management factors of German Shepherd dogs.