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Individual and group level trajectories of behavioural development in Border collies

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ABSTRACT

In order to assess dogs' personality changes during ontogeny, a cohort of 69 Border collies was followed up from six to 18–24 months. When the dogs were 6, 12, and 18–24 months old, their owners repeatedly filled in a dog personality questionnaire (DPQ), which yielded five personality factors divided into fifteen facets. All five DPQ factors were highly correlated between the three age classes, indicating that the dogs' personality remained consistent relative to other individuals. Nonetheless, at the group level significant changes with age were found for four of the five DPQ factors. Fearfulness, Aggression towards People, Responsiveness to Training and Aggression towards Animals increased with age; only Activity/Excitability did not change significantly over time. These changes in DPQ factor scores occurred mainly between the ages of 6 and 12 months, although some facets changed beyond this age. No sex differences were found for any of the tested factors or facets, suggesting that individual variation in personality was greater than male/female differences. There were significant litter effects for the factors Fearfulness, Aggression towards People and Activity/Excitability, indicating either a strong genetic basis for these traits or a high influence of the shared early environment. To conclude, from the age of six months, consistency in personality relative to other individuals can be observed in Border collies. However, at the group level, increases in fearful and aggressive behaviours occur up to 12 months and for some traits up to two years, highlighting the need for early interventions. Follow-up studies are needed to assess trajectories of personality development prior to six months and after two years, and to include a wider variety of breeds.

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1. Introduction

The notion that behavioural traits remain consistent over time is at the core of most definitions of personality (e.g. Bergmüller and Taborsky, 2010; Stamps and Groothuis, 2010). Nonetheless, even if individual behavioural differences remain stable over the short term, developmental processes can have major impacts on behaviour across contexts and time, and thus lead to long-term changes in personality (Stamps and Groothuis, 2010). In humans, an individual's personality continues to develop throughout his/her lifetime but becomes increasingly more stable with age (Roberts and DelVecchio, 2000). A meta-analysis indicated that rank order consistency (i.e. expression of personality traits relative to other individuals) increases from childhood (average trait consistency: 0.31) up into the fifties to seventies (average trait consistency: 0.74; range 0–1 with 1 corresponding to complete consistency, Roberts and DelVecchio, 2000). While individuals thus become more consistent in the expression of their personality as they get older, people in general also become less neurotic, extroverted and open, but more agreeable and conscientious with age (McCrae et al., 2000; Srivastava and John, 2003).

Surprisingly little is known about the development and consistency of individual behavioural differences in non-human animals and which factors may influence them at any given time (Stamps and Groothuis, 2010). In captive rhesus macaques (*Macaca mulatta*), some correlations in social behaviour between the ages of 8, 16, and 52 weeks (Stevenson-Hinde et al., 1980a) were found, indi-

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cating consistency at early ages. However, the same authors found no correlation using the same behavioural tests conducted once at the age of one year and repeated at 2.5 years (Stevenson-Hinde et al., 1980b). Moreover, while ratings of confidence were stable at all ages, ratings for excitability showed no consistency until adulthood and those for sociability became stable only after the age of three years, demonstrating that stability was also dependent on the trait in question (Stevenson-Hinde et al., 1980a). Similarly, in domestic cats (*Felis catus*), behavioural consistency between the age of 4 months, 1 and 2 years was variable for different traits, with boldness being one of the most consistent traits (Lowe and Bradshaw, 2001). Partial consistency of some traits (e.g. social behaviours, fearfulness and reactivity to humans) but not others (e.g. behaviours in novel object tests and responses to handling) was reported also for young horses (*Equus caballus*) that were tested between the ages of 8–11 months and 1.5–2.5 years (Lansade et al., 2008a,b; Visser et al., 2001). These studies indicate that at least some specific traits may be consistent when assessed over short time intervals, but not necessarily over long time periods.

Given the close relationship between people and domestic dogs (*Canis familiaris*), studies on dogs' behavioural development are of especially high interest due to their implications for matching puppies, juvenile or adult dogs with the right owners, identifying predispositions towards behavioural problems early on, and predicting suitability for service dog work, police or military service. A recent meta-analysis suggested that personality is moderately consistent in younger dogs (<1 year of age when tested for the first time, $r = 0.30$), and that consistency increased with age ($r = 0.51$ in dogs >1 year of age when tested for the first time) (Fratkin et al., 2013). Based on the currently available literature and in conjunction with our own results, testing at an early age (<3 months) yields little predictive validity regarding future behavioural traits, although it may play a role in identifying negative extremes (Riemer et al., 2014a). Apart from the sensitive period between 4 and either 8 (Lord, 2013) or 12–14 (Freedman et al., 1961; Scott and Fuller, 1965) weeks, we also pointed to the importance of experiences during the adolescence period in determining the adult animal's behaviour (Riemer et al., 2014a). However, much of the literature on behavioural development in dogs focuses on behaviour in puppies younger than three months and then again on adult dogs (e.g. Asher et al., 2013; Svobodova et al., 2008; Wilsson and Sundgren, 1997a), largely neglecting the adolescent period, with a few exceptions discussed below.

Goddard and Beilharz (1984) found some correlations between dogs' behaviour at 3, 4, 6 and 12 months of age and adult fearfulness, but the older the dogs became, the more reliable were the assessments (Goddard and Beilharz, 1984). Sforzini et al. (2009) found that self confidence increased from 5 to 9 months in 32 German shepherd dogs that were trained as customs working dogs. In those dogs that were selected to continue training, re-assessments at 24 months showed an increase in attentiveness, self-confidence, and ability to solve problems and retrieve objects and a decrease in playfulness. Harvey et al. (2016) tested 93 Labrador dogs destined to become guide dogs, first at 5 and again at 8 months of age. They found that several behavioural measures, including jumping, barking, low posture during greeting and mouthing, but not those related to obedience, were significantly correlated between the two age classes. Results from both tests were found to be predictive of future qualification as guide dogs. Harvey et al. (2016) do not, however, report if and in what direction behavioural changes occurred at the group level.

There is also a lack of longitudinal data on individual behavioural development in dogs. The few studies that used behavioural tests were limited to the specific stimuli presented in those tests, which were typically identical for the initial test and re-tests (and were thus no longer novel during re-testing, e.g. Harvey et al., 2016;

Sforzini et al., 2009). Moreover, some studies used a biased sample in their later assessments by re-testing only those dogs that had passed the previous evaluations (e.g. Sforzini et al., 2009). One published longitudinal questionnaire study that has demonstrated high temporal consistency in dogs was limited to a single trait, impulsivity (Riemer et al., 2014b). Similarly, cross-sectional questionnaire studies have addressed only a small selection of behavioural traits. For example, these indicated increases in calmness (Kubinyi et al., 2009) but decreases in trainability (Kubinyi et al., 2009) and sociability with age (Bennett and Rohlf, 2007; Kubinyi et al., 2009). There are, however, some inconsistencies between studies: some authors report that anxious behaviours decrease (Bennett and Rohlf, 2007) or boldness increases with age (Strandberg et al., 2005), whereas others found a decrease in boldness as dogs got older (Kubinyi et al., 2009; Starling et al., 2013). Thus, it is currently not known from what age individual differences in behaviour can be reliably characterised in dogs, when personality as such stabilises or whether each trait stabilises at a certain point and independently from others.

Therefore behavioural development was studied in a cohort of Border collies. The main aims were firstly to assess to what extent personality is consistent (relative to age mates) during different periods of development (at the ages of 6 months, 12 months, and 18–24 months) and secondly to assess in what manner behavioural traits change from adolescence at 6 months to young adult age at 1.5–2 years. To this end, we asked the dogs' owners to fill in a dog personality questionnaire at three points in time, when their dogs were 6 months, 12 months and 18–24 months old.

2. Methods

2.1. Subjects

To rule out effects of breed differences in the ontogeny of behaviour (e.g. Feddersen-Petersen, 1990; Miklósi, 2008; Scott and Fuller, 1965; Scott, 1958; Seksel et al., 1999), only members of a single breed, the Border collie, were included in the study. The choice of breed was made by convenience as this is a common breed in Austria, and contact with the dog owners was established mainly through Border collie breeders who already cooperated with the Clever Dog Lab in other studies. The Clever Dog Lab is popular with Border collie owners due to the high need for mental stimulation in this breed, and several subjects of the current study also participated in other research (e.g. Müller et al., 2016; Riemer et al., 2014a,c).

The owners of 84 dogs volunteered to participate in the study by filling in questionnaires about their dogs' behaviour when the dogs were approximately six, 12 and 18–24 months old. The ratio of female to male respondents was 63: 18, of which three female respondents filled in the survey for two dogs. The dogs (46 females, 38 males) came from 23 litters from 17 breeders, with between one and seven subjects per litter. Except for the litter mates, the sample did not contain full or half siblings. Demographic data were available for 64 of the subjects. Of these, 18.8% lived with single adults. Thirty-seven point five percent came from households with two adults and no kids, 14.1% from households with 3 or 4 adults, 25% from households with two adults and 1–3 children, 1.6% from a household with 3 adults and one child, and 3.1% from a household with one adult and 1 or 2 children. 42.2% of the dogs were the only dog in the household; 28.1% shared their home with one other dog, and 29.7% came from households with three or more dogs. The owners of 90.6% of the dogs indicated that their dogs were kept as a member of the family or companion. 71.9% of the dogs were kept for sports (including agility, obedience, search and rescue, occasional sheep herding etc.), 3.1% for working (sheep herding), and 7.8% for breeding purposes (multiple responses were possible). 35.9% of the

dogs were kept mainly in the house; 60.9% were kept partially in the house and partially in the garden, and 3.1% were kept mainly in the garden. While demographic data were available for most subjects, this was not included in the analyses since the study was not designed to balance the data in that respect nor was the sample size sufficient.

Data from all three time points are complete for 69 dogs (37 females and 32 males); the remaining owners filled in only one or two questionnaires at different time points. Only three subjects, two males and one female, were neutered during the course of the study (between the age of 6 and 12 months), and therefore data for all subjects were pooled.

2.2. Questionnaires

A Dog Personality Questionnaire (DPQ, Jones, 2008; short form; Appendix A), which has been validated regarding inter-rater reliability, test-retest reliability and predictive validity, was used with some modifications: the questionnaire was translated into German and ratings were made on a 5-point Likert scale (not a 7-point scale as in the original questionnaire) (c.f. Turcsán et al., in prep.). The questionnaire consisted of 45 questions such as "Dog is relaxed when greeting people", "Dog is curious" etc. The questionnaire yielded five personality factors (hereafter "DPQ factors") subdivided into 15 facets, or sub-level traits (Jones, 2008; Appendix A). The factor scores were calculated as in Jones (2008): each factor score consisted of the sum of scores of three facets that loaded together in the original factor analysis by Jones (2008). The German version has been tested for internal consistency on the basis of 207 dogs (Turcsán et al., in prep.), which confirmed the factor structure found by Jones (2008). Cronbach's alpha of the five factors ranged from 0.646 (Responsiveness to Training) to 0.793 (Fearfulness), demonstrating that the translation and the modification of the rating scale did not cause marked changes in the factors' structure (Turcsán et al., in prep.).

2.3. Data processing and statistical analysis

In order to assess consistency of questionnaires factors/facets across the three ages (6 months, 12 months, and 18–24 months), intra-class correlation coefficients (two way random, absolute consistency, single measures) were computed in IBM SPSS Statistics 18. Generalised Linear Mixed Models (GLMMs) were calculated in R 2.15.1 to assess group level differences between the three age classes, with sex and age class as fixed factors and ID nested within litter as random factors. If possible, factors and facets obtained from the questionnaires were normalised using single or double log transformations or square root transformations and analysed using models assuming a normal distribution (function lme, package nlme). Variables that could not be normalised due to high skewness were converted into binary variables and analysed with binomial GLMMs (function glmer/lme4). Likelihood ratio tests were used to obtain p-values for the binomial GLMMs. Predictors were removed from the models if their inclusion did not yield a better fit according to likelihood ratio tests. Thus models were reduced until only significant predictors remained, with the exception that age was retained in all models as the main variable of interest in this study. Within-model comparisons of the 12-month results with results from 6 and 18–24 months enabled localisation of significant effects. Additional models were calculated post-hoc to assess significant differences also between the ages of 6 and 18–24 months. To correct for multiple comparisons, FDR correction (Verhoeven et al., 2005) was applied. All figures were prepared in Statistica 6.1 (Statsoft Inc. 2004).

3. Results

Descriptive statistics of the dogs' DPQ scores across the three ages are shown in Appendix B. All five DPQ factors were significantly correlated between the ages of 6, 12 and 18 months (all p < 0.001, mean ICC: 0.420), indicating that the dogs' personality remained consistent relative to other individuals. Fearfulness was the most consistent trait with an ICC of 0.649, and the ICC for Aggression towards people was 0.570. The remaining factors had lower ICCs (Activity: 0.239; Responsiveness to Training: 0.325; Aggression towards Animals: 0.323). Somewhat higher ICCs were obtained when correlating individual facets rather than the composite factors (mean ICC = 0.552; ICC all >0.39; p all <0.001; Appendix C).

Despite consistency at the level of the individual, significant changes with age were found for four of the five DPQ factors at the group level (Table 1, Fig. 1). Within-model comparisons revealed that changes in DPQ factor scores occurred mainly between the ages of 6 and 12 months (i.e. increases in Fearfulness, Aggression towards Humans, and Responsiveness to Training). Aggression towards Animals had a tendency to increase both between 6 and 12 and between 12 and 18–24 months. The overall model for Activity/Excitability was not significant, although this factor tended to decrease after 12 months. Similarly at the facet level, most significant changes occurred between the first and second age class (Appendix D); however, a few facets showed significant changes beyond this age. For example, Situational Aggression remained stable between 6 and 12 months of age but showed a highly significant increase thereafter (binomial model: p = 0.006; Appendix D). Aggression towards other dogs increased significantly between 6 and 12 months (GLMM, within model comparison: p = 0.002) and tended to increase further between 12 and 18–24 months (GLMM, within model comparison: p = 0.067; Appendix D). Active Engagement (dogs' physical activity level and their interest in their environments) declined significantly after the age of 12 months (binomial model: p = 0.009; Appendix D).

No sex differences were found for any of the tested factors or facets. There were significant litter effects for the factors Fearfulness, Aggression towards People and Activity/Excitability (Table 1) and for several of the facets associated with social fear and aggression (Appendix D).

4. Discussion

This study demonstrates consistency of personality differences in Border collies from the age of six months up to 24 months while highlighting that absolute changes in personality occur with age. Fearfulness and Aggression towards People had very high individual consistency, implying that rank order of individuals remained stable over time for these traits. However, the incidence of fearful and aggressive behaviour in the sample population increased until the age of 12 months, and for some individual facets until 18–24 months. Activity/Excitability, Responsiveness to Training and Aggression toward Animals had lower individual consistency than Fearfulness and Aggression towards People but scores were still highly correlated between ages. Generally, dogs became more responsive to training with age but they also showed higher levels of aggression towards animals as they got older – in line with the observed increase in aggressive behaviour towards humans. Only Activity/Excitability did not change significantly until 18–24 months of age, although there was a trend towards a reduction between 12 and 18–24 months.

In accordance with these results, there is some evidence from repeated behavioural tests that dogs' behaviour may be consistent by the age of 5–6 months (Goddard and Beilharz, 1984: tests

Table 1

Results of minimal GLMMs testing for differences in the five DPQ factors between age groups. Since sex was not significant for any model it is not included in the table. Litter effects, if significant, are indicated in the column "Random effect(s) of best model". All significant results for the full models remained significant after correction for multiple testing.

Dependent variable	Transformation	Random effect(s) of best model	Test statistic (DF)	P full model	Within model comparison	P (within model comparison)
Fearfulness	Double Log	ID nested within litter	$F_{(2,138)} = 10.36$	0.0001	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.0006 0.431 <0.0001
Aggression towards People	Double Log	ID nested within litter	$F_{(2,138)} = 5.24$	0.0064	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.049 0.214 0.002
Activity/Excitability	Double Log	ID nested within litter	$F_{(2,138)} = 2.20$	0.12	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.930 0.064 0.073
Responsiveness to Training	None	ID	$F_{(2,138)} = 8.79$	0.0003	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.006 0.178 0.0001
Aggression towards Animals	Double Log	ID	$F_{(2,138)} = 6.92$	0.001	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.060 0.067 0.0003

repeated at 6 and 12 months; Harvey et al., 2016: tests at 5 and 8 months). Also, although no direct consistency estimates were given in Duffy and Serpell (2012), the authors report that 27 of 36 questions of the CBARQ (Canine Behavioral Assessment and Research Questionnaire) differentiated between successful and unsuccessful guide dog candidates at the age of six months, and with the exception of six questions, the same questions differentiated successful from unsuccessful dogs at 12 months of age. Thus, currently available studies indicate some consistency in personality by 5–6 months of age (with different traits having been investigated in different studies).

While there is some variability between different factors, with a mean ICC of 0.42 consistency of personality factors in the present sample was in the range to that reported by Harvey et al. (2016) for several behaviours (average of significant correlations: 0.41) and by Goddard and Beilharz (1984) for repeatability of behaviour in different tests measuring fearfulness (mean 0.354). This is higher than the mean consistency of 0.30 reported for dogs <1 year old during the initial assessment in the meta-analysis by Fratkin et al. (2013). Notably at the facet level, correlations in the current study were even higher with a mean ICC of 0.552 between the three assessments. In contrast to our study, the previous studies used behavioural tests rather than owner questionnaires (consistency between CBARQ scores between 6 and 12 months was not reported in the study by Duffy and Serpell, 2012). Since questionnaires require respondents to draw on their overall experience with the subject and are not influenced by factors specific to the test situation – as is the case for behavioural assessments – we would expect greater consistency in questionnaire results than in behaviour tests.

Of course, using questionnaires in the assessment of canine personality can have both advantages and disadvantages. On the one hand, owner questionnaires represent the summary evaluation over a longer time period and are not dependent on a single event in time from which generalisations are made (see also Hsu and Serpell, 2003). On the other hand, relying on the dogs' owners as informants could potentially lead to less accurate or more biased assessments compared to expert assessments, as well as to a less independent sample since the same owners fill in the questionnaires repeatedly. However, validity of the German version of the DPQ used has been demonstrated by significant correlation of results with components obtained from a dog personality test (Turcsán et al., in prep.), and the original (English) version of the DPQ has been thoroughly validated for many aspects of reliability and validity (Jones, 2008). Moreover, a few studies have demonstrated overall good corre-

spondence between lay peoples' assessments of dogs' behaviour in a behaviour test and those made by experts (Fratkin et al., 2015; Mirkó et al., 2013). Additionally, Mirkó et al. (2013) compared questionnaire ratings made by dogs' owners with evaluations made by independent observers based on video recordings of a dog personality test and found agreement between owners and independent raters on three out of four behavioural traits. Only aggressiveness was consistently rated to be lower by owners than by independent raters, possibly due to an artefact of the test situation, in which the dog was threatened in a way not normally occurring in everyday life (Mirkó et al., 2013).

While it can thus not be excluded that owners might underestimate the level of traits in dogs that they consider undesirable, the significant changes in fearfulness as well as aggressive behaviour with age observed demonstrate owners' ability to notice such changes in their pets. Likewise, it is possible that the owners overestimated consistency in their dogs' behaviour due to recall bias interfering with their assessments. However, the significant changes in scores over time for the majority of factors and facets indicate that the owners were sensitive to changes in their dogs' behaviour at least to some extent. Furthermore it cannot be ruled out that certain behaviours were more salient to the owners than others, leading to reporting of stronger changes than for traits that may be expressed less overtly. Nonetheless, the facet level analysis demonstrates that owners clearly differentiated, for example, between different types of fears as they reported an increase in fear of people and non-social fear, but not fear of dogs. Similarly, they differentiated between general aggression and situational aggression. This gives us confidence that even if absolute consistency estimates may be somewhat affected by owner biases, the direction of changes reported truly reflects behavioural changes in the dogs.

Despite consistency at the level of the individual (relative to age mates), significant changes were observed in four of the five DPQ factors between the ages of 6 and 18–24 months. In our sample of Border collies, fearfulness in both the social and non-social domain increased with age. Also, Starling et al. (2013) report that boldness decreased significantly with age in dogs of various breeds, based on a cross-sectional questionnaire survey. Contrarily, Sforzini et al. (2009) and Strandberg et al. (2005) found an increase in boldness with age in German Shepherds. Thus, on a cautionary note, the current results may not apply to all breeds in the same way, and it is conceivable that different breeds develop at different rates and
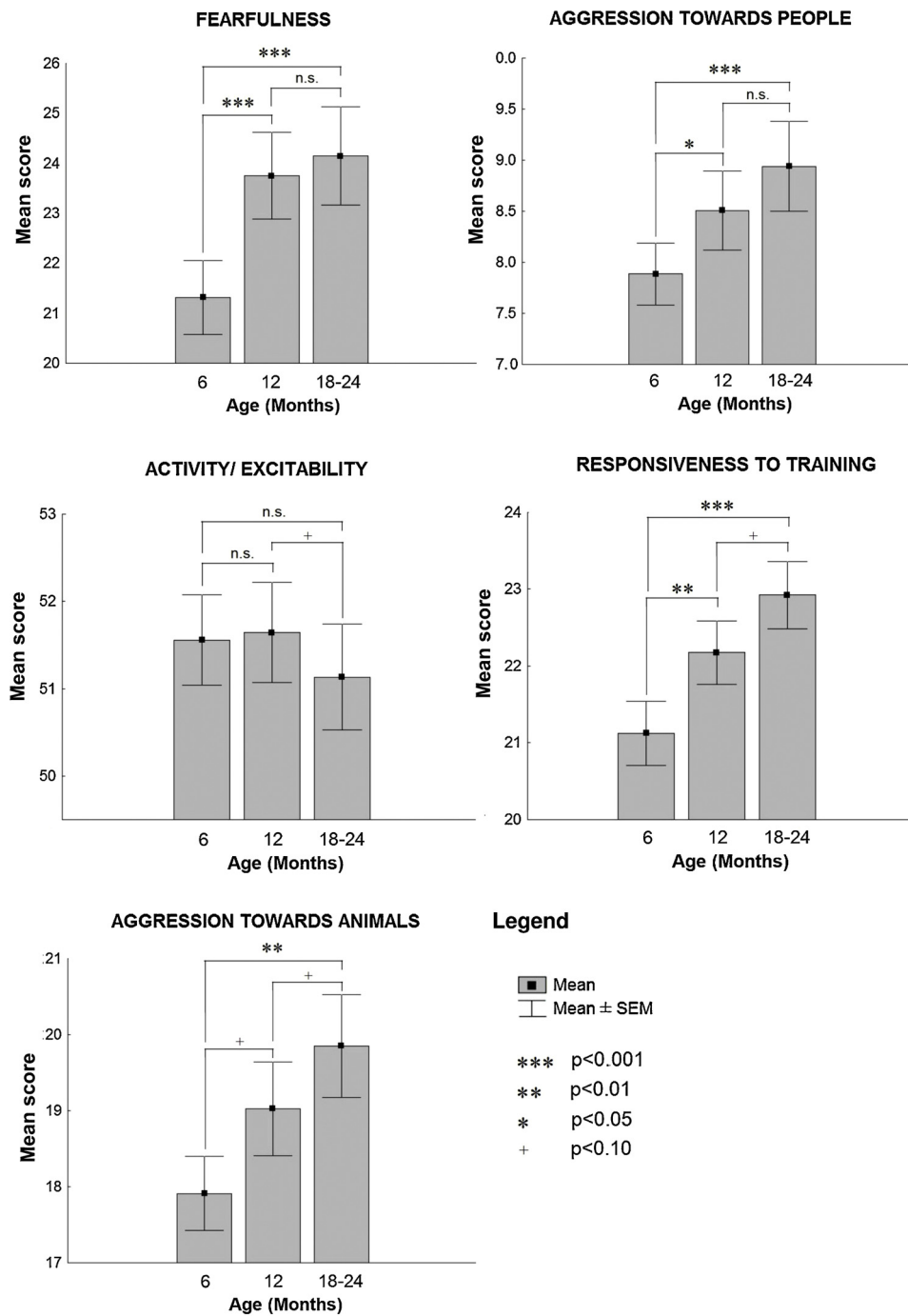
Fig. 1. Visualisation of change in scores of the DPQ factors between age groups (6 months, 12 months, 18–24 months).

possibly in different directions (see also Morrow et al., 2015; on breed-specific differences in puppies' behavioural development).

In the current study, aggression towards humans and conspecifics increased between 6 and 12 months, and additionally some individual facets, such as situational aggression (directed towards humans) and dog directed aggression increased between 12 and 18 months. The observed increases in aggression towards both people and dogs are in agreement with previous findings in a variety of breeds. For example, Bennett and Rohlf (2007) report an increase in aggression towards people and other dogs with age, and likewise the risk of aggression towards unfamiliar people increased significantly with age in the study Casey et al. (2014).

Previous studies indicate that generalised anxiety/fear, noise phobia (Overall et al., 2006), as well as aggression towards humans and conspecifics (Liinamo et al., 2007; Overall et al., 2006) often occur sometime between one and two years of age (Overall et al., 2006). Some of these changes, especially those related to fearfulness, appeared even earlier in our sample, between 6 and 12 months. This implies that some indications of behavioural problems may be apparent already at a relatively young age – and should thus be addressed through behaviour modification as soon as possible to avoid the manifestation of more severe behavioural problems.

None of the investigated traits differed between the sexes, suggesting that at least in Border collies, individual variation in

personality is greater than between male and female personalities. This is in agreement with some other studies that found no significant sex differences in behaviour in domestic dogs (Foyer et al., 2013; Gazzano et al., 2008; Seksel et al., 1999). Sex differences in behaviour may also be breed specific (Van der Waaij et al., 2008; Wilsson and Sundgren, 1997b) or may become more pronounced when the animals become older (c.f. Gazzano et al., 2008; Seksel et al., 1999).

Litter effects were significant for Fearfulness, Aggression towards People and Activity/Excitability, but not for Responsiveness to Training and Aggression towards Animals. The first three factors clearly have a biological basis, and some genetic and physiological factors contributing to these traits in domestic dogs have been identified (e.g. Hejjas et al., 2007; Liinamo et al., 2007; Van der Waaij et al., 2008; Vermeire et al., 2009). In contrast, responsiveness to training is a fuzzier concept that might consist of different characteristics such as sensitivity to reward as well as sensitivity to punishment. Additionally, it is likely that this factor will be strongly shaped by the dogs' training experiences (e.g. Arhant et al., 2010; Blackwell et al., 2008; Herron et al., 2009; Hiby et al., 2004). Finally, the Aggression towards Animals factor included both predatory behaviours towards small animals and social behaviour towards conspecifics and is thus somewhat incoherent. Very different emotions, and thus different underlying biological systems, may be underlying these behaviours, and this may explain the lack of litter effect for this factor. However, at the facet level, Aggression towards Dogs was significantly affected by litter, in line with the finding for Aggression towards People.

In any case the significant effect of litter on the majority of factors indicates either a strong genetic basis for these traits or a high influence of the shared early environment. Our data do not allow distinguishing between these possibilities (or to assess the relative contribution); however, both genetic factors (Liinamo et al., 2007; Murphree and Newton, 1971; Saetre and Strandberg, 2006; Wilsson and Sundgren, 1997a) and early rearing environment (Appleby et al., 2002; Freedman et al., 1961; Scott and Fuller, 1965; Strandberg et al., 2005) have been shown to influence adult dog behaviour, which emphasises the breeders' responsibility in selecting stud dogs and ensuring careful early socialisation.

5. Conclusions

From the age of six months, consistency in personality relative to other individuals can be observed in Border collies, especially in relation to fearful and aggressive behaviour. However, at the group level, behavioural changes arise with age. Increases in fearful and aggressive behaviour occur up to 12 months and for some traits up to 1.5–2 years, highlighting the need for early interventions. Follow-up studies are needed to assess trajectories of personality development prior to six months and after two years. Furthermore, given evidence of breed specific differences in behaviour, behavioural development and heritability of traits (Feddersen-Petersen, 1990; Scott, 1958; Wilsson and Sundgren, 1997a,b), breed specific patterns of personality development should be assessed.

Acknowledgements

Appendix A.

Factors, facets and individual questions of the DPQ (short form, Jones, 2008) and internal consistency of factors, calculated from the German translation of the questionnaire (Turcsán et al., in prep.). Numbers in the second column represent the original numbers of the questions in the questionnaire. In the current study, the owners were asked to rate their agreement with the German translation of the statements on a 5-point Likert scale ("sehr unzutreffend", "eher unzutreffend", "teils-teils", "eher zutreffend", "sehr zutreffend"), which can be freely translated as "disagree strongly", "tend to disagree", "partly-partly", "tend to agree", "agree strongly".

Factor 1 – Fearfulness		Cronbach's alpha: 0.793
	Facet 1 – Fear of People	
	1*	Dog is relaxed when greeting people.
	6	Dog is shy.
	27	Dog behaves fearfully towards unfamiliar people.
	Facet 2 – Nonsocial Fear	
	3	Dog is anxious.
	11*	Dog is confident.
	22*	Dog adapts easily to new situations and environments.
	Facet 3 – Fear of Dogs	
	13	Dog avoids other dogs.
	21	Dog behaves submissively (e.g., rolls over, avoids eye contact, licks lips) when greeting other dogs.
	42	Dog behaves fearfully towards other dogs.
	Facet 4 – Fear of Handling	
	16	Dog behaves fearfully during visits to the veterinarian.
	35	Dog exhibits fearful behaviours when restrained.
	44	Dog behaves fearfully when groomed (e.g., nails trimmed, brushed, bathed, ears cleaned).
Factor 2 – Aggression towards People		Cronbach's alpha: 0.707
	Facet 1 – General Aggression	
	7	Dog behaves aggressively towards unfamiliar people.
	18*	Dog is friendly towards unfamiliar people.
	40	Dog shows aggression when nervous or fearful.
	Facet 2 – Situational Aggression	
	25	Dog behaves aggressively in response to perceived threats from people (e.g., being cornered, having collar reached for).
	30	Dog behaves aggressively during visits to the veterinarian.
	36	Dog aggressively guards coveted items (e.g., stolen item, treats, food bowl).
Factor 3 – Activity/Excitability		Cronbach's alpha: 0.683
	Facet 1 – Excitability	
	15	Dog is boisterous.
	31	Dog seeks constant activity.
	41*	Dog tends to be calm.
	Facet 2 – Playfulness	
	9*	Dog gets bored in play quickly.
	17	Dog enjoys playing with toys.
	33	Dog retrieves objects (e.g., balls, toys, sticks).

Facet 3 – Active Engagement
4* Dog is lethargic
14 Dog works at tasks (e.g., getting treats out of a Kong, shredding toys) until entirely finished.
24 Dog is curious.

Facet 4 – Companionability
20 Dog seeks companionship from people.
26* Dog is aloof.
37 Dog is affectionate.

Factor 4 – Responsiveness to Training	Cronbach's alpha: 0.646

Facet 1 – Trainability
29* Dog is slow to respond to corrections.
38* Dog ignores commands.
43 Dog is able to focus on a task in a distracting situation (e.g., loud or busy places, around other dogs).

Facet 2 – Controllability
5 When off leash, dog comes immediately when called.
10* Dog is quick to sneak out through open doors, gates.
32 Dog leaves food or objects alone when told to do so.

Factor 5 – Aggression towards Animals	Cronbach's alpha: 0.673

Facet 1 – Aggression towards Dogs
2 Dog behaves aggressively toward dogs.
19* Dog is playful with other dogs.
34* Dog is friendly towards other dogs.

Facet 2 – Prey Drive
8 Dog likes to chase squirrels, birds, or other small animals.
23 Dog likes to chase bicycles, joggers, and skateboarders.
39 Dog behaves aggressively towards cats.

Facet 3 – Dominance over other Dogs
12 Dog is dominant over other dogs.
28* Dog willingly shares toys with other dogs.
45 Dog is assertive or pushy with other dogs (e.g., if in a home with other dogs, when greeting).

Note: Items marked with an asterisk are reverse coded items.

Appendix B.

Mean (bolded) and interquartile range of DPQ factor scores in the three age groups

Age group	Fearfulness	Aggression towards People	Activity/Excitability	Responsiveness to Training	Aggression towards Animals
6 months	**21.32** (16–25)	**7.89** (6–9)	**51.56** (49–54)	**21.13** (18–24)	**17.91** (14–21)
12 months	**23.81** (18.25–28.75)	**8.50** (6–9.75)	**51.54** (48–55)	**22.20** (20–24)	**18.96** (15–22)
18–24 months	**24.27** (19–28.5)	**8.99** (6–10)	**50.96** (47.5–54.5)	**22.99** (20.5–26)	**19.85** (16–22.5)

Appendix C.

Intra-class correlation coefficients (two way random, absolute consistency, single measures) between facets at 6, 12 and 18 months. All results are significant after correction for multiple testing.

Facet	ICC	P
Fear of People	0.68	<0.001
Nonsocial Fear	0.65	<0.001
Fear of Dogs	0.58	<0.001
Fear of Handling	0.56	<0.001
General Aggression	0.64	<0.001
Situational Aggression	0.45	<0.001
Excitability	0.55	<0.001
Playfulness	0.64	<0.001
Engagement	0.39	<0.001
Companionability	0.41	<0.001
Trainability	0.51	<0.001
Controllability	0.47	<0.001
Aggression towards Dogs	0.53	<0.001
Prey Drive	0.63	<0.001
Dominance over other Dogs	0.59	<0.001

Appendix D.

Results of minimal GLMMs testing for differences in DPQ facets between age groups. Variables that were log10, double log or square-root transformed or were normally distributed without transformation were analysed with GLMMs assuming a normal distribution (F statistics presented). Variables transformed into binary variables were analysed with binomial models (Chi^2 statistics presented). Litter effects, if significant, are indicated in the column "Random effect(s) of best model". All significant results for the full models remain significant after FDR correction for multiple testing.

Dependent variable	Transformation	Random effect(s) of best model	Test statistic (DF)	P full model	Within model comparison	P 6 vs 12 months and 12 vs 18 months
Fear of People	log10	ID nested within litter	$F_{(2,138)} = 7.72$	0.0007	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.002 0.737 0.0006
Nonsocial Fear	log10	ID	$F_{(2,138)} = 8.85$	0.0002	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.020 0.064 0.0001
Fear of Dogs	log10	ID	$F_{(2,138)} = 0.57$	0.57	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.414 0.317 0.825
Fear of Handling	double log	ID nested within litter	$F_{(2,138)} = 7.38$	0.0009	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.002 0.651 0.0007
General aggression	binary	ID; Litter (p = 0.007)	$X^2_{(2)} = 253.61$	0.2636	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.237 0.699 0.127
Situational aggression	binary	ID; Litter	$X^2_{(2)} = 280.35$	0.009	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.873 0.006 0.008
Excitability	log10	ID	$F_{(2,138)} = 2.95$	0.056	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.020 0.097 0.551
Playfulness	binary	ID	$X^2_{(2)} = 274.66$	0.8679	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.913 0.691 0.610
Active Engagement	binary	ID	$X^2_{(2)} = 273.43$	0.0133	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.796 0.009 0.010
Companionability	binary	ID	$X^2_{(2)} = 272.41$	0.7894	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.489 0.568 0.924
Trainability	log10	ID	$F_{(2,138)} = 2.40$	0.09	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.110 0.616 0.040
Controllability	none	ID	$F_{(2,138)} = 11.09$	<0.0001	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.003 0.093 <0.0001
Aggression towards Dogs	double log	ID nested within litter	$F_{(2,138)} = 19.48$	<0.0001	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.002 0.003 <0.0001
Prey Drive	square-root	ID	$F_{(2,138)} = 0.03$	0.97	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.813 0.891 0.927
Dominance over other Dogs	none	ID	$F_{(2,138)} = 2.64$	0.075	6 vs 12 months 12 vs 18–24 months 6 vs 18–24 months	0.104 0.550 0.030

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